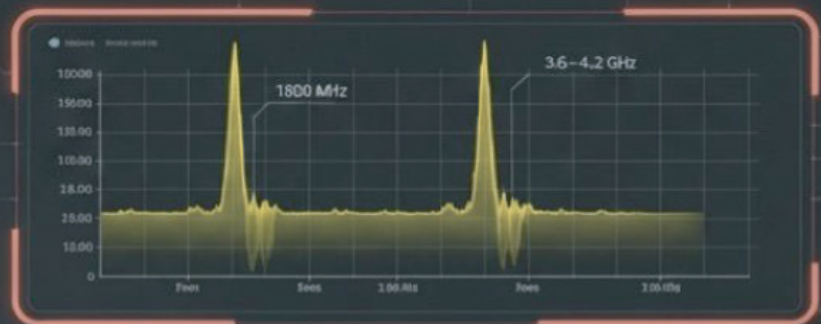


# TECHNICAL ANALYSIS OF NON-PUBLIC NETWORKS IN KENYA

Focus on 1800 MHz and 3.6-4.2 GHz Bands



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## Acronyms

|          |                                                     |
|----------|-----------------------------------------------------|
| AFRALTI  | African Advanced Level Telecommunications Institute |
| ASA      | Authorised Shared Access                            |
| ATU      | African Telecommunications Union                    |
| CA       | Communications Authority of Kenya                   |
| CBRS     | Citizens Broadband Radio Services                   |
| CNSP     | Community Network Service Provider                  |
| DSA      | Dynamic Spectrum Alliance                           |
| FDD      | Frequency Division Duplex                           |
| GIS      | Geographic Information Systems                      |
| GSA      | Global Mobile Suppliers Association                 |
| FWA      | Fixed Wireless Access                               |
| IMT      | International Mobile Telephony                      |
| ITU      | International Telecommunication Union               |
| LTE-A    | Long-Term Evolution - Advanced                      |
| LTE      | Long-Term Evolution                                 |
| LSA      | Licensed Shared Access                              |
| MNO      | Mobile Network Operator                             |
| OFDMA    | Orthogonal Frequency Division Multiple Access       |
| P5G      | Private 5G                                          |
| TRAFICOM | Finnish Transport and Communications Agency         |
| QoS      | Quality of Service                                  |
| TDD      | Time Division Duplex                                |



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## Executive Summary

This report examines the technical feasibility of enabling Non-Public Networks (NPNs) in Kenya through opportunistic and shared access arrangements in the 1800 MHz band and the C-Band (3.6–4.2 GHz). The work examines the technical assessment and interpretation to determine coverage, coexistence and sharing approaches to assess the feasibility of deploying Private LTE and 5G networks while ensuring that the primary services in the identified bands are protected from harmful interference. The analysis has been done with consideration of the technical requirements specified by standards and regulatory bodies such as the 3rd Generation Partnership Project (3GPP), the International Telecommunication Union (ITU), other regulatory regimes as well as the Communications Authority of Kenya (CA) in the identified bands. Key publications from global spectrum innovation advocacy groups, particularly the Dynamic Spectrum Alliance (DSA), have also provided great technical insight regarding considerations of coexistence in the 700 MHz – 3 GHz frequency range.

Hence, the analysis presented in this report has consolidated inputs from desk-based assessments on coverage and coexistence, site visit measurements (including RF spectrum measurements) from select sites in Kajiado County, datasets from CA as well as technical coexistence analysis using SEAMCAT and MATLAB tools for the 1800 MHz and C-band respectively.

The 1800 MHz analysis indicates that NPN deployment could help address selected coverage gaps, particularly in rural and underserved areas. However, unrestricted co-channel operation near incumbent MNO sites may cause unacceptable degradation. For the modelled scenarios, coexistence performance improved when NPN transmit power, antenna height and coverage area were limited and when appropriate separation or coordination measures were applied. The study therefore recommends that any initial NPN deployments be authorised on a controlled, site-specific basis, using provisional conditions such as a maximum transmit power of 1 W, an antenna height of up to 20 metres and a target coverage radius of approximately 2.5 km. The proposed 15 km separation distance should be treated as an initial coordination or trial parameter rather than a universally applicable national exclusion zone.

The C-band analysis focuses on the potential deployment of Private 5G as a Fixed Wireless Access (FWA) at Orly Park (a selected site in Kajiado) while protecting the Fixed-Satellite Service (FSS) earth station at RMS Brackenhurst in Limuru. The modelling produces a 70 km separation result for the specific single-base-station scenario examined. This result is dependent on the assumed frequency, propagation conditions, transmitter characteristics and FSS receiver parameters and should not be interpreted as a general national separation distance. The analysis does not assess all relevant interference mechanisms, including UE-to-FSS interference, multiple simultaneous NPN deployments, short-term interference, blocking, or coexistence with future public IMT deployments. The report recommends that CA establishes a coordinated and technology-neutral framework for NPN trials. Applications should be assessed on a case-by-case basis using accurate information on incumbent MNO, FSS and proposed NPN sites as well as GIS and propagation characteristics. A central database or coordination mechanism should be used to record deployments and determine technical conditions. Further work should validate the propagation and interference assumptions through additional measurements and sensitivity analyses. Priority should be given to analysing multiple NPN deployments, UE-to-FSS interference, adjacent-channel operation, future public IMT deployment in the C-band, actual FSS receiver characteristics and the effect of different antenna heights, transmit powers and traffic activity levels. Subject to this further work, controlled NPN trials could provide useful evidence for developing proportionate national sharing conditions in Kenya.

# Introduction

According to 3GPP, Non-Public Networks (NPNs) have gained popularity with the emergence of 5G specifications, catering for use cases that require optimised coverage, reduced latency, isolation, privacy and security, as well as granular control over network resources. However, the concept has existed in previous cellular generations, depending on the adopted configuration. Notably, with the capability to support high-speed data rates and the ability to support a wide range of applications and devices, experiences provided by LTE-based technologies (LTE-Advanced) and LTE-Advanced Pro have made the adoption of Private LTE networks possible.

LTE-based private networks are currently in use to provide wireless coverage in specific areas and facilities such as campuses, factories and warehouses. These private networks support the mobile workforce, industrial equipment monitoring, asset tracking, etc., with improved performance, measured by a combination of metrics such as bandwidth, latency, Quality of Service (QoS), security and customisation.

Between 2011 and 2014, Finland trialled a Licensed Shared Access/Authorised Shared Access (LSA/ASA) model in the 2.3-2.4 GHz band, in which a Private LTE Time Division Duplex (TDD) implementation with a software radio testbed was evaluated. This trial led to the adoption of a local 4G/5G regulatory approach by the Finnish Transport and

Communications Agency (TRAFICOM), allowing local mobile network deployments in select geographical areas.

Similar developments of Private LTE/5G have emerged using either licensed mobile spectrum or shared-access spectrum, such as the Citizens Broadband Radio Service (CBRS) spectrum in the United States of America (USA), or local access licenses. The latter are becoming more prevalent with 5G now that specific bands for local 5G use have been made available in several markets, with prominent examples in the 1800 MHz (for LTE) in Asia-Pacific, 3.7-3.8 GHz in Germany, 3.8-4.2 GHz in the UK and 2570-2620 MHz in France.

Achieving shared-access models or local-access licenses for Private LTE/5G requires proper management of sharing arrangements. Such arrangements require consideration of predetermined conditions that are well established in the international frequency allocations and informed by a complex range of international, regional and national coexistence measures. This report demonstrates the technical feasibility of deploying Private LTE in Kenya in the 1800 MHz band and Private 5G in the 3.6-4.2 GHz frequency bands, while ensuring that the defined incumbent systems are not degraded by harmful interference.



# Technical Analysis in the 1800 MHz

Before the standardisation of LTE in 2004, 3GPP highlighted the following basic requirements for LTE as part of the Universal Terrestrial Radio Access Network (UTRAN):

- Scalable bandwidth between 1.4 MHz and 20 MHz.
- Enhanced consumer experience with high data rates (peak data rate) exceeding 100 Mbps in downlink (DL) and 50 Mbps in uplink (UL).
- Reduced latency with radio round-trip time below 10 ms and access time below 300 ms.
- Increased spectral efficiency.
- Reduced network complexity and packet-switched domain optimisation.

LTE aimed to offer long-term benefits through its progression to a statistical multiplexing technique called Orthogonal Frequency Division Multiple Access (OFDMA) – and this has held to date (and adopted in 5G New Radio (5G-NR) - that provides a higher spectral efficiency. OFDMA provides multiple access connectivity by using both time and frequency division to assign resources to individual users, in order to provide the highest and most efficient throughput. In Europe, the allocated frequency bands for LTE (for both DL and UL) include 800 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2300 MHz and 2600 MHz [1].

In Kenya, the International Mobile Telephony (IMT) spectrum has been allocated in the 700 MHz, 800 MHz, 900 MHz, 1800 MHz, 2100 MHz and the 2600 MHz frequency bands. The 1800 MHz band is presently assigned on a paired basis (Frequency

Division Duplex – FDD) to all Mobile Network Operators (MNOs) with 10 MHz bandwidth slices as shown in Table 1. Safaricom implements carrier aggregation in the band to achieve the 45 MHz bandwidth. According to the latest allocations in Kenya, 1800 MHz (1710-1920 MHz) is allocated to both Fixed Wireless Access (FWA) and IMT.

At the same time, an analysis of the diverse deployments by mobile network operators (MNOs) in the 1800 MHz band in Kajiado West reveals a significant disparity in the number of sites deployed within the region. Notably, Safaricom dominates the deployments in this area, owning a substantial 99.310% of the sites. Airtel holds approximately 0.6896% of the sites, while Telkom and Jamii Telecommunications (JTL) have no sites deployed yet.

In the 2024/2025 NPN Analysis, the 1800 MHz (1710-1785/1805-1880) was identified as having potential for shared access in Kenya. The Global Mobile Suppliers Association (GSA) refers to the 1800 MHz (Band 3) as the most popular global band for LTE with 137 countries/territories using the band for the provision of services or as part of a multi-band deployment. According to GSA's database, there are 327 LTE or LTE-Advanced networks that are using Band 3. Similar to Europe and Kenya, Ofcom has also assigned the band for LTE with the 1781.7 – 1785 MHz (uplink) and 1805 – 1876.7 MHz (downlink) authorised for shared access.

Table 1: Current MNO Assignments in Kenya

| MNO                                      | 800 MHz | 900 MHz | 1800 MHz | 2100 MHz |
|------------------------------------------|---------|---------|----------|----------|
| Airtel Networks Kenya Limited (Airtel)   | 2x10    | 2x10    | 2x10     | 2x20     |
| Safaricom PLC (Safaricom)                | 2x10    | 2x17.5  | 2x45     | 2x30     |
| Telkom Kenya Limited (Telkom)            | 2x10    | 2x7.5   | 2x10     | 2x10     |
| Jamii Telecommunications Limited (Jamii) | 0       | 0       | 2x10     | 0        |

## Site Visits and Measurements

As part of the technical analysis, the following sites were visited in Kajiado County: Olepolos Site in Kisamis, Olepolos Quarry, Sham’s camp Il Ngaroj, Saikeri Market, Umma University, Kipeto Wind Farm, Oltepesi(Tinga) and Lake Magadi (Tata chemicals industry). The visits were jointly undertaken by representatives from The African Advanced Level Telecommunications Institute (AFRALTI), the Communications Authority of Kenya (CA), Aegir Consult, Strathmore University and Namelok Community Network (Namelok CNSP), between January 26th and 31st 2026. The technical site assessments included spectrum measurements led by CA, GIS data collection and spatial assessments, power availability, and backhaul capacity assessment.

The sites represented a mix of community service points, institutional facilities, commercial and industrial operations, and critical infrastructure, providing a strong basis for evaluating diverse NPN use cases.

In this report, distinct zones have been created for the eight sites, primarily based on the presence of Namelok CNSP infrastructure and the sites’ potential for NPN deployment. The zoning approach is guided by Namelok’s CNSP proximity to existing incumbent infrastructure in the respective areas. In addition, this zoning also considers the sites based on future deployment in the 1800 MHz band or the C-Band (3600 MHz to 4200 MHz). The report, therefore, presents the four proposed zones and the distribution of incumbent infrastructure and existing Namelok infrastructure as follows in Table 2:

Table 2: NPN Study Zone Description

| Zone Name | Incumbent Sites                                            | Focus Band                  | Namelok Site                                                                                                |
|-----------|------------------------------------------------------------|-----------------------------|-------------------------------------------------------------------------------------------------------------|
| Zone A    | Safaricom Site 374                                         | 1800 MHz                    | Site III: Saikeri Market                                                                                    |
| Zone B-1  | Safaricom Site 431                                         | 1800 MHz                    | "Site I: Olepolos, Kisamis Corner<br>Site II: Quarry<br>Site VIII: Sham's Camp II Ngaroj"                   |
| Zone B-2  | Safaricom Site 379                                         | 1800 MHz                    | "Site I: Olepolos, Kisamis Corner<br>Site II: Quarry<br>Site VIII: Sham's Camp II Ngaroj"                   |
| Zone C    | Safaricom Site 127                                         | 1800 MHz                    | SiteVI: Oltepesi(Tinga)                                                                                     |
| Zone D    | Closest FSS Site Downlink<br>(RMS Brackenhurst<br>Limuru.) | C band – 3600<br>– 4200 MHz | "Site IV: Umma University<br>Site V: Kipeto Wind Farm<br>Site VII: Lake Magadi (Tata<br>Chemicals Factory)" |

## Site I: Olepolos, Kisamis Corner

The Olepolos Kisamis site was established by Namelok CNSP to serve the surrounding community by hosting the first network tower given the availability of grid power at the site. This provides a stable and reliable power supply suitable for the present Namelok's telecommunications infrastructure that serves approximately 45 customers through the 2.4 GHz and 5 GHz Wi-Fi, each user receiving an average of 5 Mbps.

Spectrum measurements in the 1800 MHz (at 1800 MHz centre frequency) using CA's portable spectrum analyser on the January 29th, 2026, showed activity in the 1815 and 1882.5 MHz range transmitted above an approximate noise floor of -8.5 dB (-115.5 dBm) as shown in Figure 1.

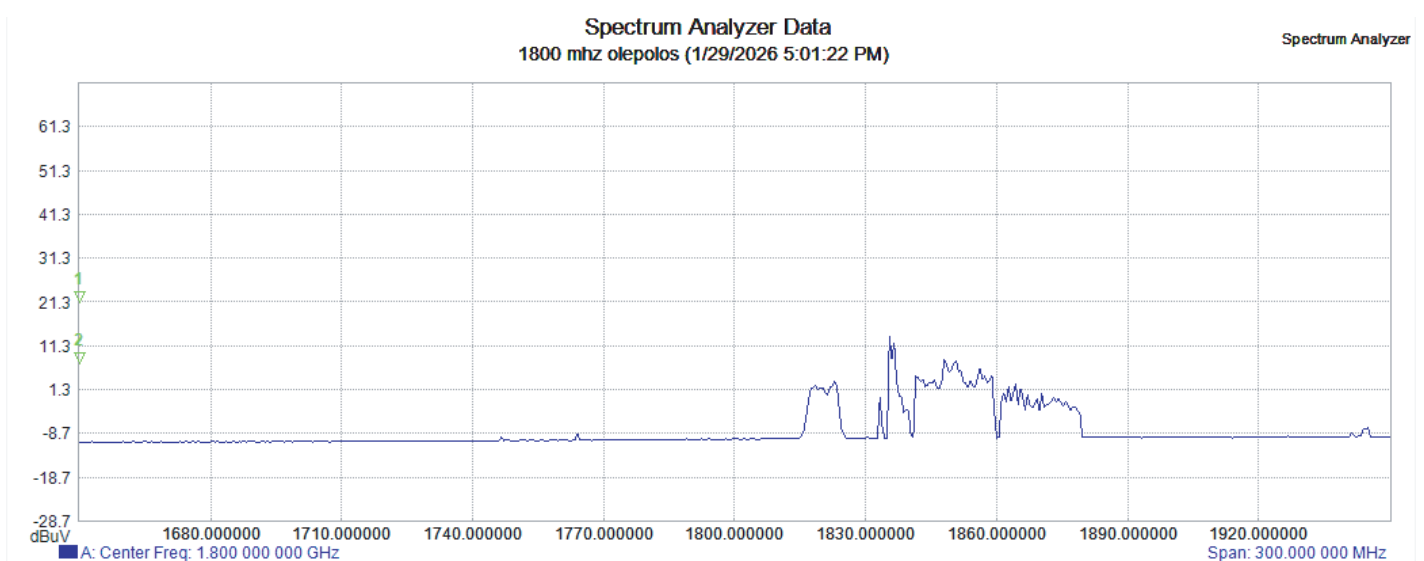
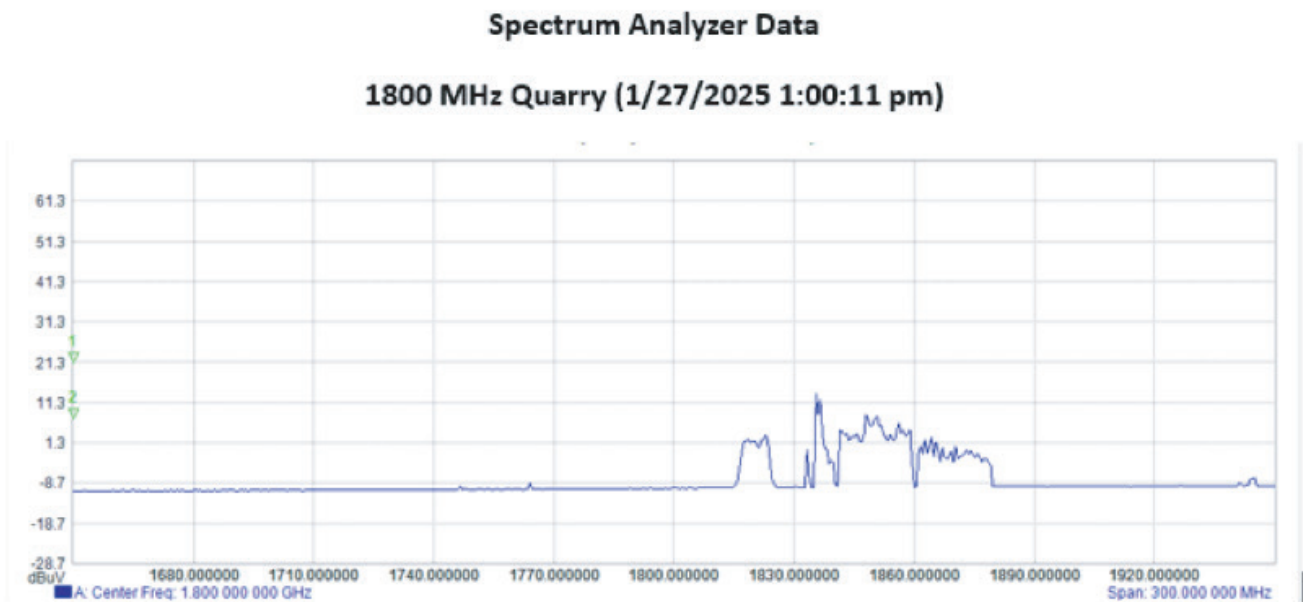


Figure 1: Spectrum measurements at the Olepolos Kisamis site

## Site II: Olepolos Quarry

The Olepolos Quarry site is a ballast mining facility about 3km from the Namelok tower at Kisamis and is surrounded by semi-arid vegetation. The facility has access to reliable power and quarry management expressed interest in automation, particularly for invoicing systems and expansion of their smart surveillance cameras –making it a potential site for NPN deployment that can support Industrial Internet of Things (IoT).

Spectrum measurements in the 1800 MHz (at 1800 MHz centre frequency) using CA’s portable spectrum analyser on the January 27th, 2026 showed activity in the band similar to the Kisamis site, as shown in Figure 2.

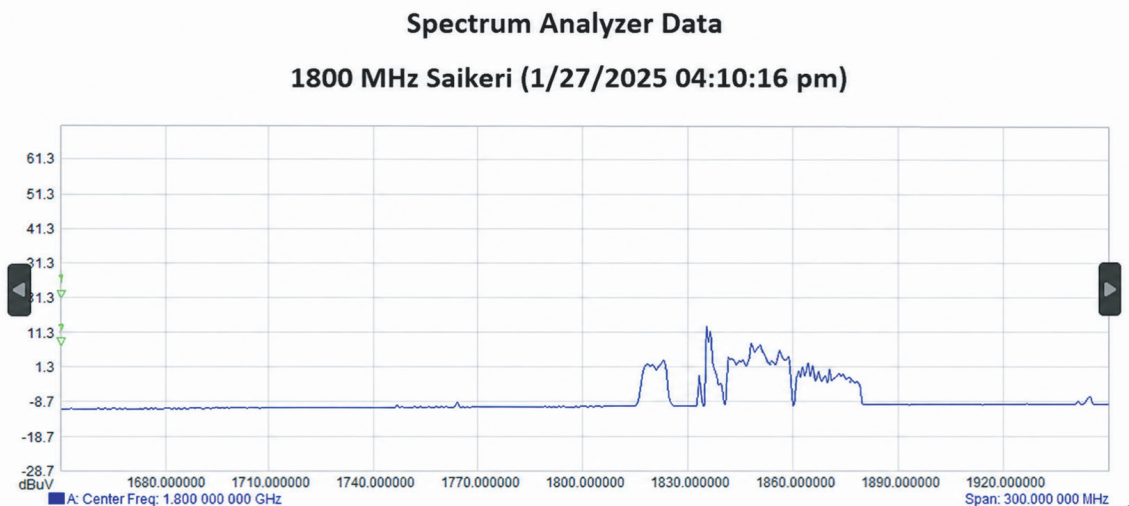


*Spectrum measurements at the Olepolos Quarry site*

## Site III: Saikeri Market

The Saikeri Market site provides Wi-Fi hotspot access with high usage recorded during market days. Similar to Site I – Oleoplos Kisamis Corner and Site II – Olepolos Quarry, the site has reliable grid power.

Spectrum measurements in the 1800 MHz (at 1800 MHz centre frequency ()) using CA’s portable spectrum analyser on January 27th. 2026 showed activity in the band of the signals transmitted above an approximate noise floor of -8.5 dB (-115.5 dBm) as shown in Figure 3.



*Figure 3: Spectrum measurements at the Saikeri MARKET SITE*

## Site IV: Umma University

Umma University is a private institution of higher learning located near Isinya in Kajiado County, serving approximately 1,000 students. Umma University hosts a diverse group of researchers. The university management expressed interest in IoT research and development of applications and confirmed future plans to establish a Cisco Academy. They also highlighted plans to expand their Research and Innovation (RI) faculty.

The institution welcomed the proposal to establish a private 5G network as a testbed environment and requested capacity building for selected staff. The identified use cases for this private network include:

- IoT applications;
- Mini data centres;
- Cisco Academy training;
- Public conference facilities for county-level meetings.

Spectrum measurements in the 1800 MHz using CA's portable spectrum analyser on the January 28th, 2026 were conducted both on the ground level (at 1850 MHz centre frequency) and at the tallest building rooftop (at 1900 MHz centre frequency), and showed spectral activity depicted in Figures 4 and 5.

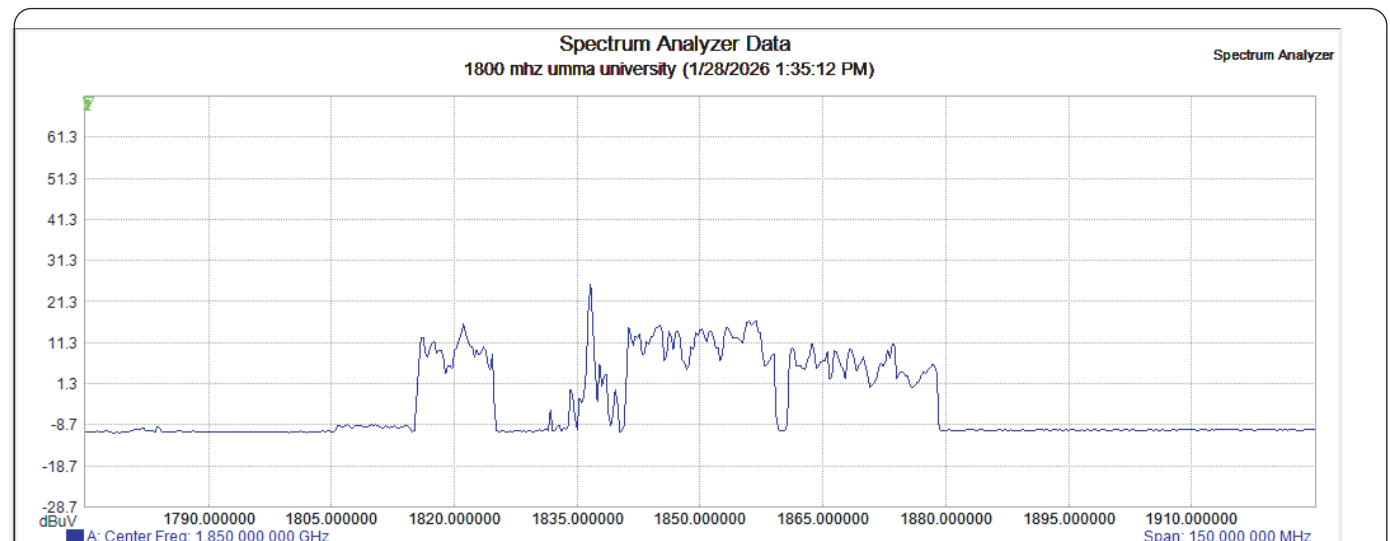


Figure 4: Spectrum measurements at the Umma University site

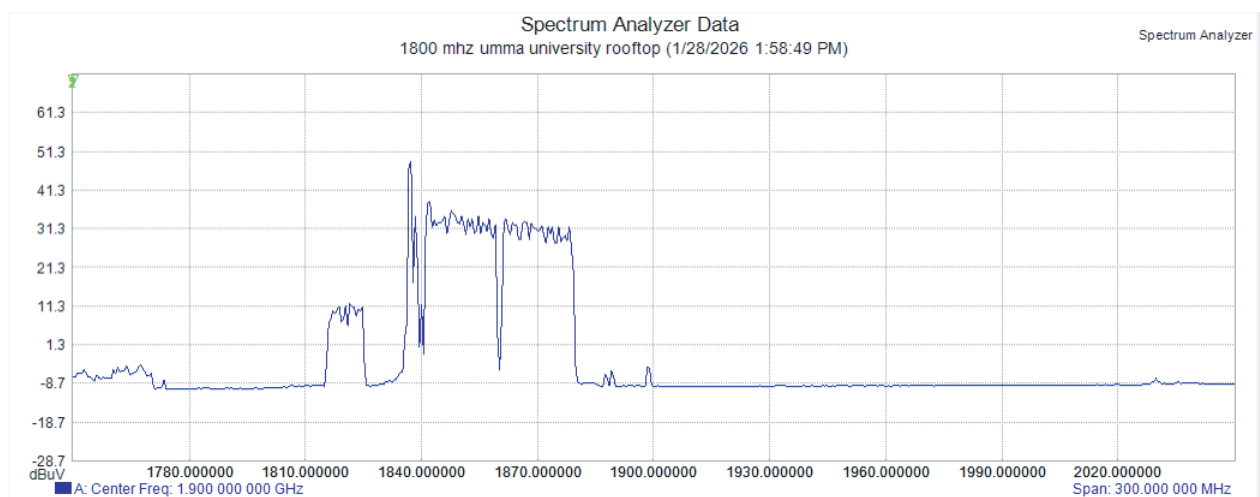


Figure 5: Spectrum measurements at the Umma University rooftop site

## Site V: Kipeto Wind Farm

Kipeto Wind Farm is a private renewable energy facility located in the Esilanke area of Kajiado County, operating 60 wind turbines producing approximately 100 MW. The facility has approximately 60 staff members and holds great potential for Industry 4.0 applications, including proposed real-time video monitoring systems to replace current binocular-based observation. The windfarm is also supporting community development through the construction of schools, one dispensary, and two hospitals. There are also plans to add same number of wind turbines to attain a capacity of 200 MW of power.

The site includes wind measurement towers and multiple observation points used for environmental and wildlife monitoring, particularly for vultures within the conservancy area. Spectrum measurements in the 1800 MHz (at 1900 MHz centre frequency) using CA's portable spectrum analyser on the January 28th, 2026 showed spectral activity as shown in Figure 6.

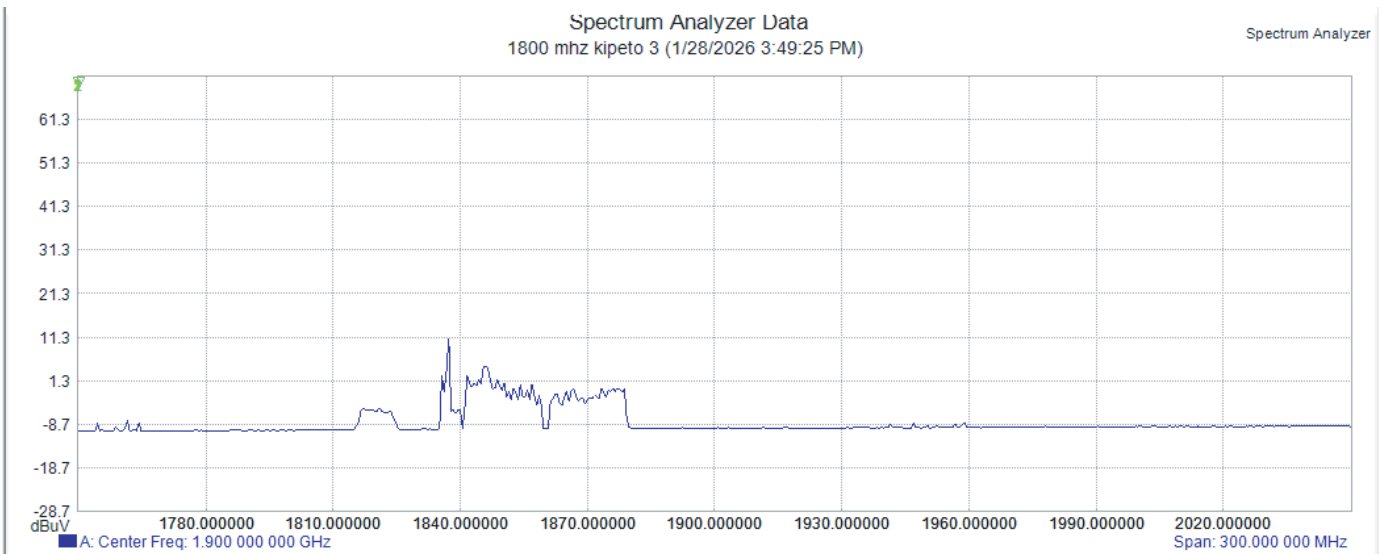


Figure 6: Spectrum measurements at the Kipeto Windfarm site

## Site VI: Oltepesi (TINGA)

Tinga Oltepesi Health Center is a public Level 3 health facility in Kajiado West, serving approximately 200 patients per week. The facility is completing a new maternity wing designed to accommodate expectant mothers from the seventh month of pregnancy, reducing risks associated with home deliveries.

The facility has adopted digital tools for service enhancement, including smart televisions for localised educational content on maternal and child health. It also operates 3 computer workstations and 15 tablets used by clinical and administrative staff.

Namelok Community Network Service Provider has a dedicated 10 Mbps connectivity link to the facility at no cost. The connection supports Social Health Authority (SHA) processing, Kenya Medical Supplies Agency (KEMSA) related correspondences, Online meetings and training sessions, and Continuous Professional Developments (CPDs) streaming of educational content for expectant and lactating mothers, and monitoring of the current solar power system.

The facility management expressed strong appreciation for the reliability of the current connectivity. However, concerns were raised regarding increased bandwidth demand following the commissioning of the maternity wing and the expansion of digital health services. The management expressed strong support for expanded coverage through an NPN solution to improve service quality, reliability, and scalability. The facility is fully solar powered, providing a stable and reliable power supply suitable for telecommunications infrastructure. Spectrum measurements in the 1800 MHz (at 1800 MHz centre frequency) using CA's portable spectrum analyser on the January 29th 2026 showed spectral activity as shown in Figure 7.

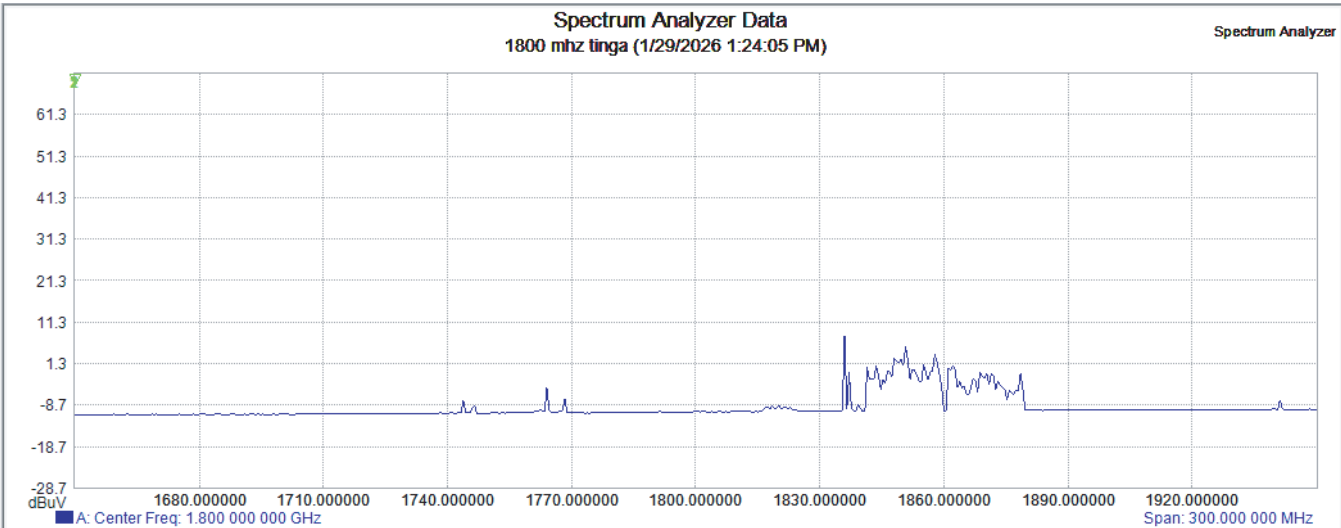


Figure 7: Spectrum measurements at the Oltepesi (Tinga) site

## Site VII: Lake Magadi (Tata Chemicals Factory)

Tata Chemicals Magadi is a large-scale salt and soda ash manufacturing facility located at Lake Magadi, Kajiado County. The management expressed an interest in automating industrial operations through enhanced connectivity. Particularly, investigating IoT solutions in this mining vertical. Spectrum measurements in the 1800 MHz (at 1800 MHz centre frequency) using CA's portable spectrum analyser on the January 29th, 2026 showed spectral activity as shown in Figure 8.

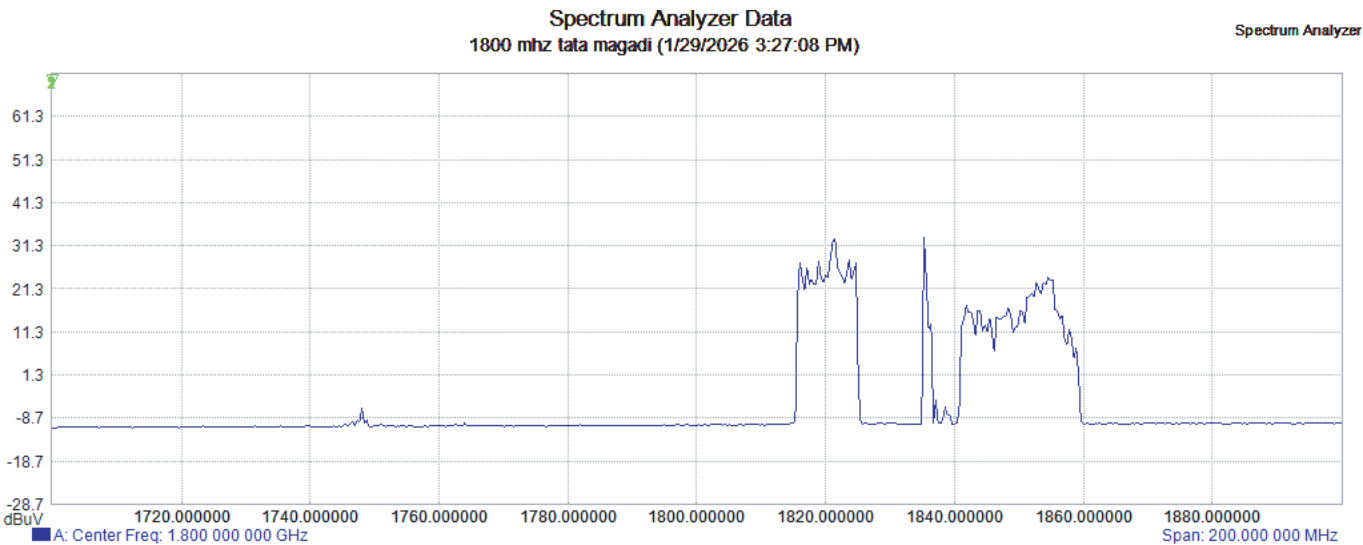


Figure 8: Spectrum measurements at the Lake Magadi (Tata Chemicals) site

# Site VIII: Sham’s Camp li ngaroj

Sham’s Camp is an existing Namelok site located at Il Ngaroj with established wireless connectivity infrastructure. The site has reliable grid power suitable for telecommunications infrastructure. The site also serves as a repeater station for backhaul connectivity to other Namelok sites; in addition to providing connectivity to local community centres, health centres, homes, farms and small and medium enterprises.

Spectrum measurements in the 1800 MHz (at 1800 MHz centre frequency) using CA’s portable spectrum analyser on the January 27th, 2026, showed spectral activity as shown in Figure 9.

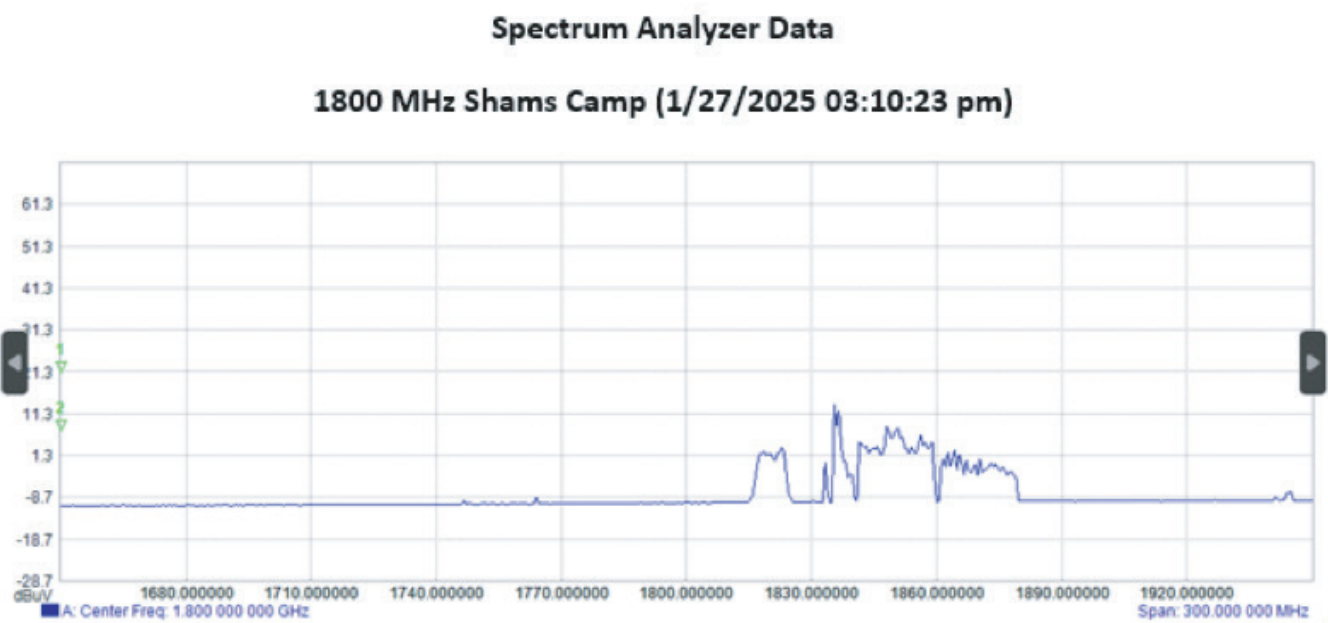


Figure 9: Spectrum measurements at the Sham’s Camp Il Ngaroj site



# Coverage Analysis

The coverage analysis examines the LTE coverage provided by the MNOs in the 1800 MHz band, particularly for the eight sites visited during the field measurements exercise, where Namelok CNSP has already deployed its Wi-Fi-based community networks. The objective of this analysis is to demonstrate the extent of LTE coverage by the MNOs and identify any coverage gaps. Additionally, we demonstrate the potential coverage that can be provided by the deployment of NPNs in the band, focusing on the initial target areas for the planned testbeds deployments.

The locations of NPN towers have been modelled based on the existing infrastructure, including towers currently owned by Namelok. The coverage calculation was performed using the HTZ ATDI tool. This report models coverage both in the downlink

and uplink direction. This is because coverage in the uplink direction ensures that the User Equipment (UE) can sustain a connection with the Evolved Node B (eNodeB). Additionally, the coverage analysis divided the area of interest, Kajiado West, into four Zones: Zone A (Kimuka-Saikeri), Zone B-1 Kisamis Corner, Zone B-2 Kisamis Market, and Zone C Oltepesi Tinga as described in Section 3.

The zoning was guided by the proximity to Namelok sites and the existing infrastructure from MNOs. Before the coverage analysis, this study was guided by technical recommendations from Standards Development Organisations (SDOs) regarding inputs such as receiver sensitivity, receiver threshold, and loss calculations. These preliminary findings are discussed in the subsequent section.

## Preliminary Parameters and Assumptions

The coverage analysis is modelled based on the technical standards recommendations that give insight into the following values:

- The UE Receiver sensitivity for modelling according to European Telecommunications Standards Institute (ETSI) Technical Specification (TS) 136 10 recommendations for Evolved Universal Terrestrial Radio Access (EUTRA) band 3 at 10MHz bandwidth and QPSK modulation is -94dBm.
- The recommended Receiver threshold, Reference Signal Received Power (RSRP), for standard LTE values in this study was adopted from ETSI TS 136 133 as -115 dB; this is the standard cell edge limit for a usable LTE connection.
- We assumed the worst-case scenario for additional losses, which were modelled based on similar radio planning guidelines, propagation models and vendor-specific considerations.
- The loss values for Kajiado West, a rural area, NPN deployment are assumed as follows in Table 3:

| Loss                                   | Value  | Consideration                                                         |
|----------------------------------------|--------|-----------------------------------------------------------------------|
| Body loss                              | 3 dB   | To cater for data and voice on handheld devices                       |
| Penetration loss                       | 12 dB  | Specific range for Rural / Suburban (Residential areas and buildings) |
| Shadow fading margin                   | 6 dB   | Rural areas                                                           |
| Handover margin loss                   | 1.5 dB | Baseline for low mobility pedestrian users                            |
| "TX loss"                              | 0.5    | Transmitter losses                                                    |
| Total additional losses for this study | 23 dB  | *Used as an additional value to the coverage threshold parameter      |

Table 3: Assumed Loss Values

In the uplink direction, the following parameters in Table 4 are used for uplink coverage considerations and analysis.

| Parameter                     | Value    | Consideration                                                            |
|-------------------------------|----------|--------------------------------------------------------------------------|
| Height of TX antenna          | 1.5m     | Standard average for UE held at hand                                     |
| TX frequency                  | 1800 MHz | *This matches the RX radio parameters                                    |
| TX radiated power             | 0.2W     | Standard for mobile UE communicating to TX towers (eNB)                  |
| Max antenna gain              | 0.00     | Assumption for all UEs                                                   |
| Distance (radius) to TX Tower | 12km     | Matches cell radius for Downlink coverage estimations recommended by CA. |
| Minimum Coverage value dBU    | 30       | Matches cell radius for Downlink coverage estimations                    |
| Wanted threshold              | 45       | Matches cell radius for Downlink coverage estimations                    |

Table 4: Uplink Coverage Parameters

To analyse the coverage of the different zones in this study, a coverage threshold criterion based on the Received Signal Received Power (RSRP) is considered. The coverage threshold based on RSRP and associated colour on the coverage map is shown in Table 5.

| RSRP Coverage Threshold | Verdict               | Colour on the coverage map                                  |
|-------------------------|-----------------------|-------------------------------------------------------------|
| $\geq -73$ dBm          | Good signal           | Warm colours (Red/Orange/Yellow)                            |
| -77 dBm to -85 dBm      | Fair/ Reliable signal | Different shades of green colour – light green is the worst |
| -89 dBm to -97 dBm      | Poor and weak signal  | Shades of blue – dark blue is the worst                     |
| Below -97dBm            | No signal             | A blank space on the map                                    |

Table 5: Coverage Threshold Based on RSRP Values

## Present Coverage Analysis: Zone A (Kimuka-Saikeri)

These parameters are for Safaricom's Site 374 and are used to model Safaricom's LTE coverage within this zone for both DL and UL. Figure 10 the coverage of Zone A by Safaricom's LTE network in site 374.

Table 6: Coverage Parameters Safaricom Site 374

| "Parameters Site(s)"                                                  | Safaricom Site 374 – 167 LTE (FDD)                                           |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Power                                                                 | 3W                                                                           |
| Frequency                                                             | 1800 MHZ                                                                     |
| TX Gain                                                               | 15.51dBi                                                                     |
| EIRP                                                                  | 95.08703W                                                                    |
| TX losses                                                             | 0.5db                                                                        |
| Antenna Height                                                        | 43.8m                                                                        |
| TX/RX Bandwidth                                                       | 10MHZ                                                                        |
| Propagation Model                                                     | ITU-P542-18                                                                  |
| Technology                                                            | LTE FDD                                                                      |
| Sub Carrier Spacing                                                   | 15KHz                                                                        |
| Total RBs                                                             | 50                                                                           |
| Total Subcarriers                                                     | 600                                                                          |
| RB bandwidth                                                          | 180KHz                                                                       |
| Antenna Radiation                                                     | Isotropic                                                                    |
| Antenna Tilt                                                          | 0°                                                                           |
| Activity Uplink                                                       | 100%                                                                         |
| Activity Downlink                                                     | 100%                                                                         |
| TX Clutter /RX Clutter                                                | Provided in HTZ Software as DEM (Digital Elevation/Terrain Model) Maps       |
| RX Threshold dBu                                                      | 45 *conversion of (-97dBm) to field strength 45dBμV/m                        |
| Coverage Threshold dBu                                                | 68.3 * addition of RX threshold (45. BμV/m) and additional losses (23dB)     |
| RSRP (Reference Signal Received Power) Receiver Sensitivity threshold | "-115 dBm"                                                                   |
| KTBF (dBm) Thermal noise floor                                        | -97dBm                                                                       |
| C/I Requirement                                                       | -6.00 / -6.00                                                                |
| Height of RX antenna                                                  | 1.5m                                                                         |
| Cut off distance                                                      | 12km * Based on Communication Authority Max. Range in Rural areas guidelines |
| Minimum Coverage value dBu                                            | 30                                                                           |
| Wanted threshold                                                      | 45                                                                           |

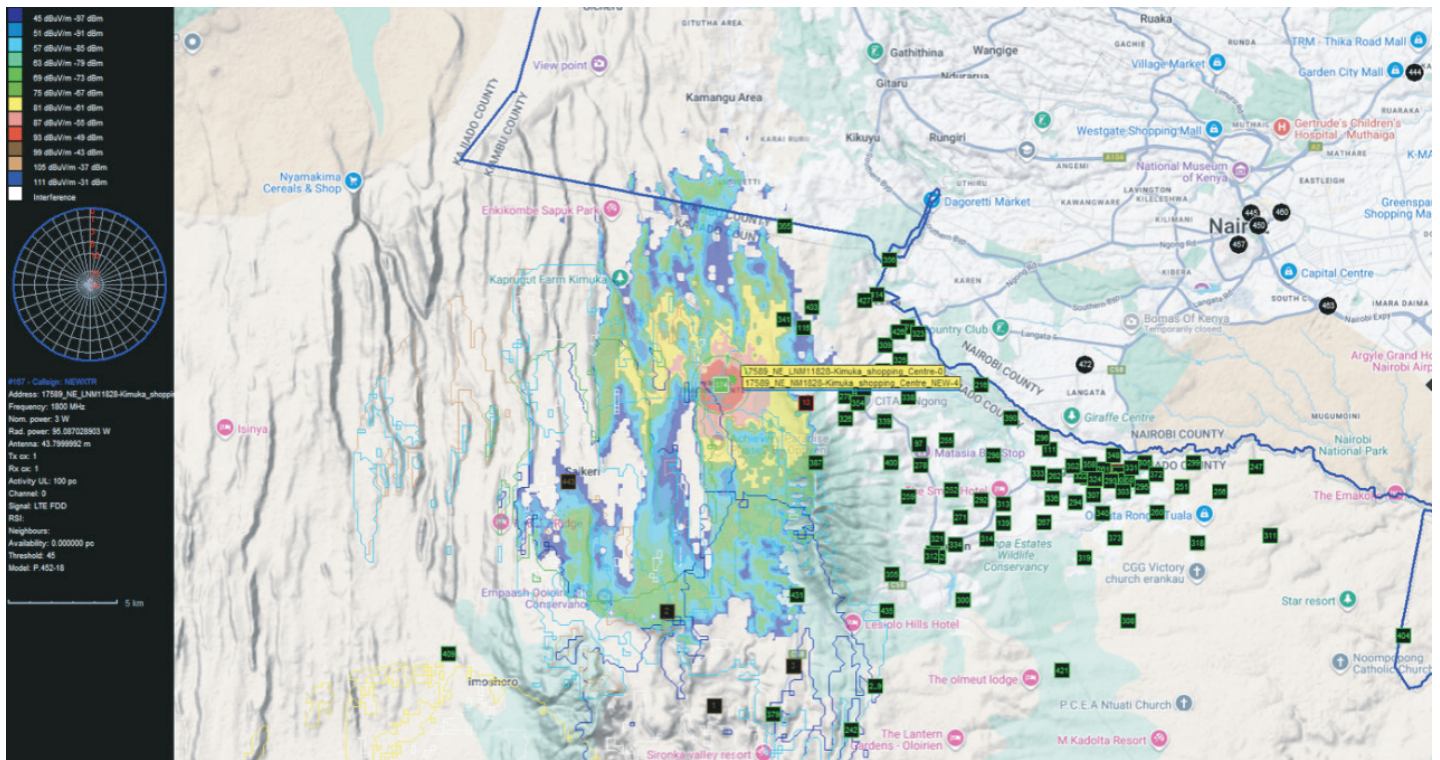


Figure 10: Zone-A Kimuka Coverage from Safaricom's LTE Site 374 Downlink

In the downlink direction, Zone A Kimuka receives relatively satisfactory reception from Safaricom's LTE site. However, the signal is noticeably obstructed by the Ngong hills to the right. Simultaneously, the signal strength deteriorates towards the west i.e. towards Saikeri. There are distinct gaps in the valleys leading up to Saikeri that lack coverage. Two of these locations are marked on the map as empty spaces. Consistently, the signal drops below -89 dBm to -97 dBm in the northern direction towards the Kamagut area and the southern direction.

In the uplink direction, Zone A Kimuka reception deteriorates. The obstruction in the eastern region by the Ngong hills persists. Furthermore, the signal significantly weakens across the entire area. The coverage area with an RSRP of more than -77dBm diminishes. While poor reception is observed towards the north, the coverage gap widens in the south and is particularly prominent in the west. This clearly indicates a degraded uplink coverage in Zone A, Kimuka, resulting in substantial coverage gaps due to the MNOs' site placement and deployment.

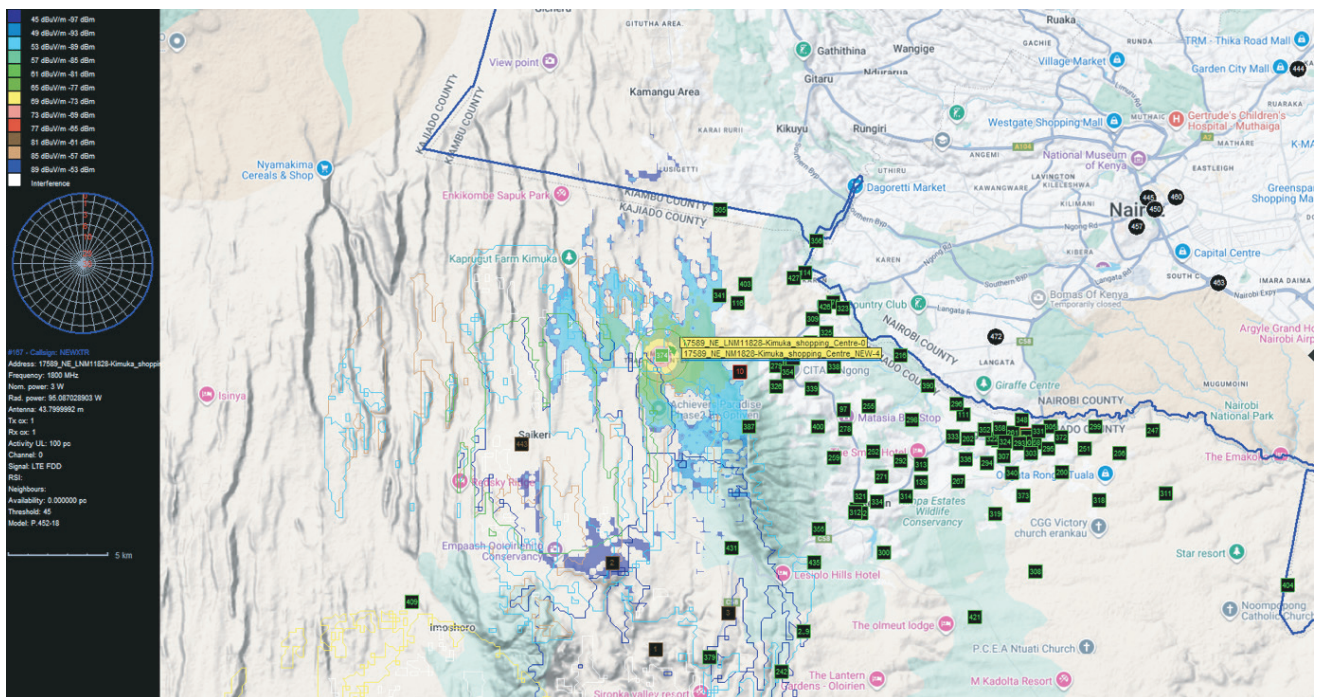


Figure 11: Zone-A Kimuka Coverage from Safaricom's LTE Site Uplink



## Potential NPN Coverage Analysis for Zone A: Kimuka-Saikeri Site

The proposed NPN Parameters for Saikeri as a potential site for deployment are shown in Table 7.

Table 7: Coverage Parameters NPN Saikeri

| " Site(s) Parameters                                                  | Saikeri NPN Site LTE (FDD)                                                   |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Power                                                                 | 1W                                                                           |
| Frequency                                                             | 1800 MHZ                                                                     |
| TX Gain                                                               | 3.5dBi                                                                       |
| EIRP                                                                  | 1.995262W                                                                    |
| TX losses                                                             | 0.5dB                                                                        |
| Antenna Height                                                        | 20m                                                                          |
| TX/RX Bandwidth                                                       | 10MHZ                                                                        |
| Propagation Model                                                     | ITU-P542-18                                                                  |
| Technology                                                            | LTE FDD                                                                      |
| Sub Carrier Spacing                                                   | 15KHz                                                                        |
| Total RBs                                                             | 50                                                                           |
| Total Subcarriers                                                     | 600                                                                          |
| RB bandwidth                                                          | 180KHz                                                                       |
| Antenna Radiation                                                     | Isotropic                                                                    |
| Antenna Tilt                                                          | 0°                                                                           |
| Activity Uplink                                                       | 100%                                                                         |
| Activity Downlink                                                     | 100%                                                                         |
| TX Clutter /RX Clutter                                                | Provided in HTZ Software as DEM (Digital Elevation/Terrain Model) Maps       |
| RX Threshold dBu                                                      | 45 *conversion of (-97dBm) to field strength 45dBμV/m                        |
| Coverage Threshold dBu                                                | 68.3 * addition of RX threshold (45. BμV/m)and additional losses (23dB)      |
| RSRP (Reference Signal Received Power) Receiver Sensitivity threshold | "-115 dBm"                                                                   |
| KTBF (dBm) Thermal noise floor                                        | -97dBm                                                                       |
| C/I Requirement                                                       | -6.00 / -6.00                                                                |
| Height of RX antenna                                                  | 1.5m                                                                         |
| Cut off distance                                                      | 12km * Based on Communication Authority Max. Range in Rural areas guidelines |
| Minimum Coverage value dBu                                            | 30                                                                           |
| Wanted threshold                                                      | 45                                                                           |

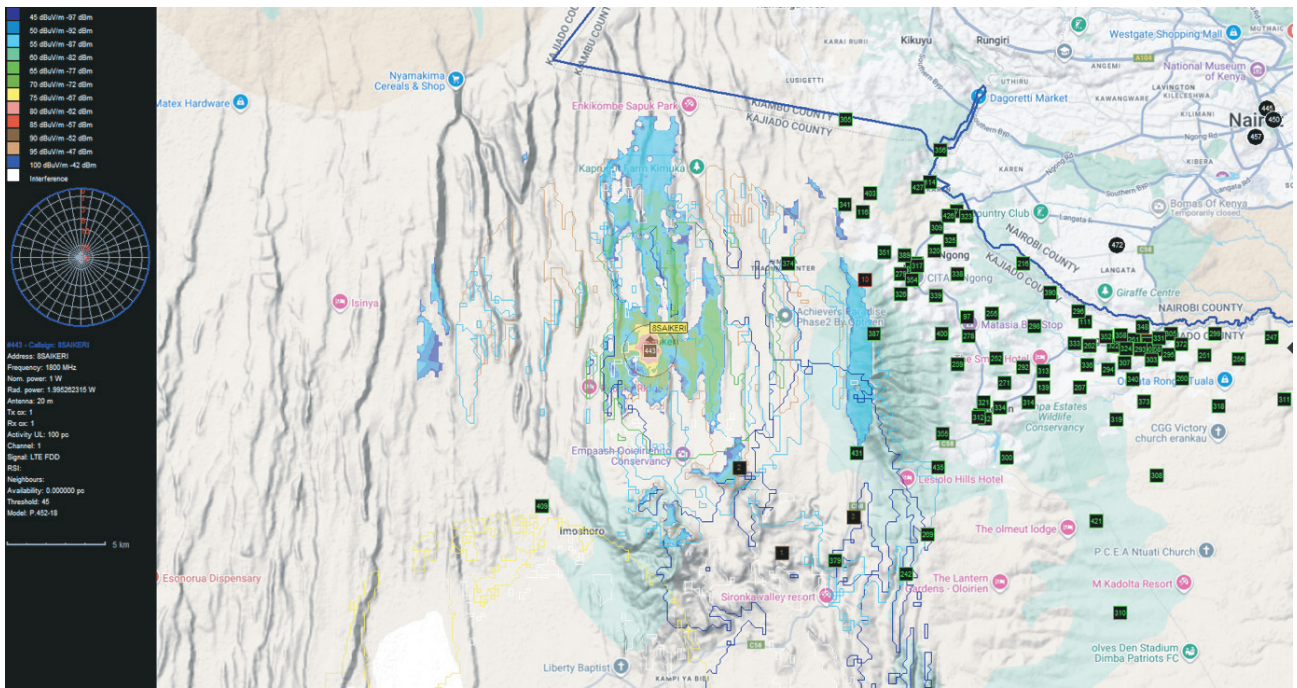


Figure 12: Downlink Coverage Analysis for Zone-A Kimuka- Saikeri NPN Potential Site

Downlink coverage results modelled using the NPN parameters outlined above in Figure 10 for Zone -A, Kimuka Saikeri, show satisfactory reception, particularly in areas where the mobile network operators (MNOs) sites were unable to provide coverage. The coverage gaps left by the MNO near the Saikeri tower consistently demonstrate a signal strength above -85dBm. Furthermore, this signal extends to the east towards Ngong Hills and to the west towards Isinya. However, these signals are weak, with a signal strength below -89dBm.

In the Uplink direction, the signal coverage from the NPN site at Saikeri decreases but consistently demonstrates the potential to provide reception to users situated in the valley near the Saikeri NPN tower, as shown in Figure 11. This coverage still complements the coverage gap that Safaricom's MNO site was unable to cover with its tower at Kimuka.

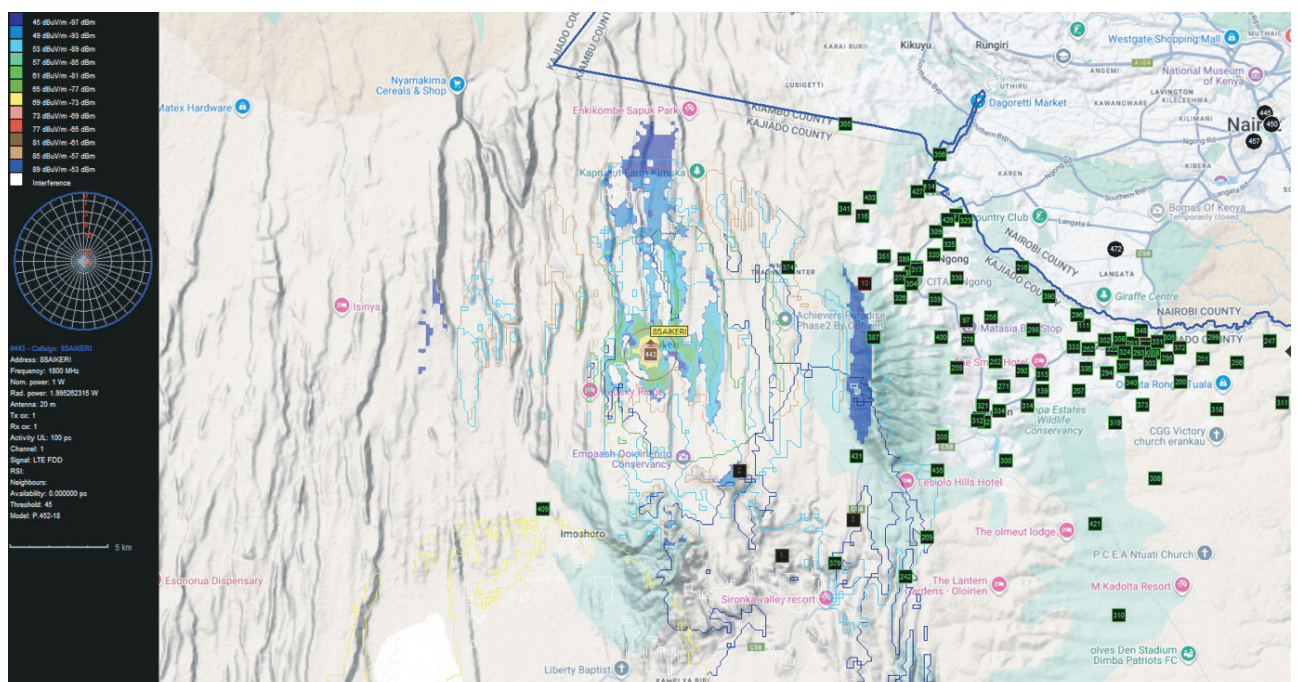


Figure 13: Uplink Coverage Analysis for Zone-A Kimuka- Saikeri NPN Potential Site



## Composite Coverage Analysis (Safaricom's LTE+NPN): Kimuka-Saikeri Site

The composite coverage maps for Zone A – Kimuka – Saikeri, presented in Figures 12 and 13, demonstrate an enhanced coverage area for both the uplink and downlink directions. Notably, the coverage gap has been significantly reduced compared to the standalone coverage analysis conducted for the Safaricom MNO site previously discussed. This suggests that Namelok's NPN site has the potential to augment coverage in the area while coexisting with Safaricom's site at Kimuka.

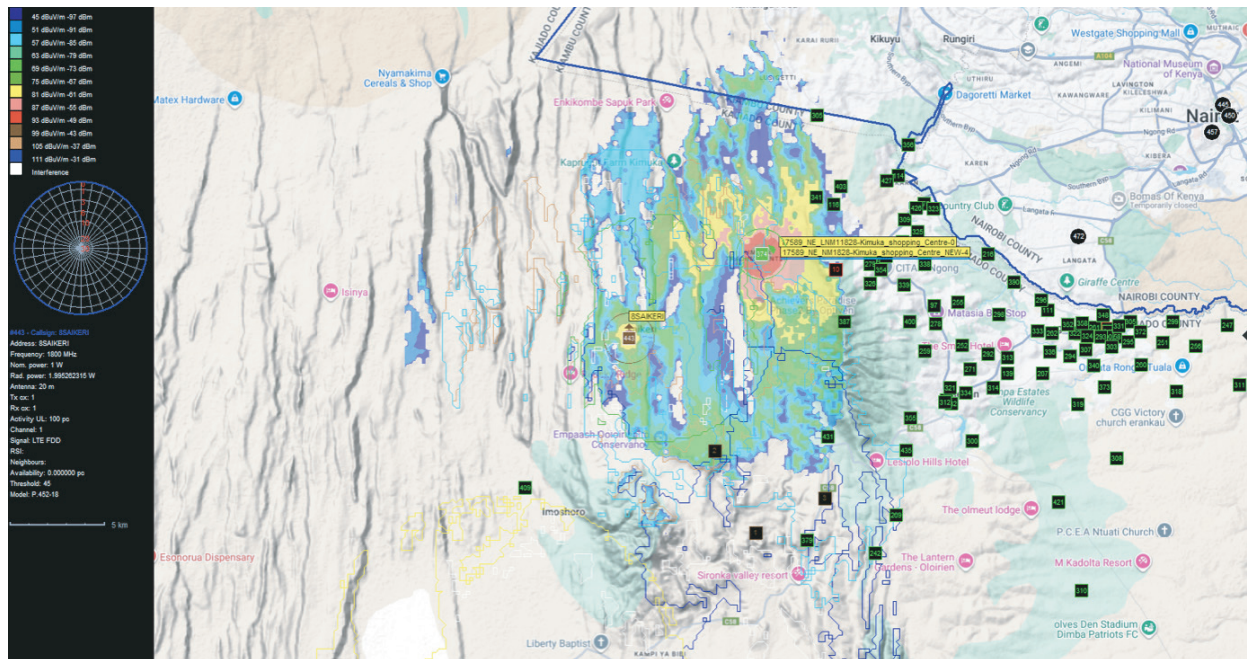


Figure 14: Zone-A Kimuka Composite Downlink Coverage Analysis (Safaricom's LTE + Potential NPN)

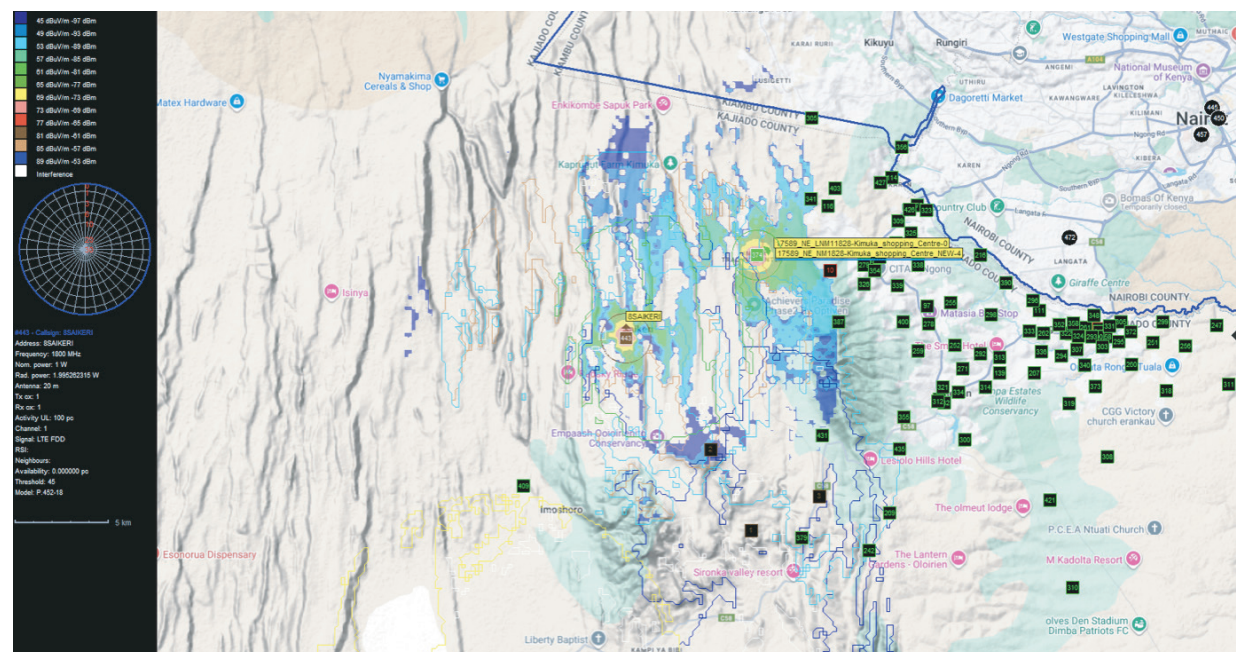


Figure 15: Zone-A Kimuka Composite Downlink Coverage Analysis (Safaricom's LTE + Potential NPN)

## Zone A – Kimuka - Saikeri Best Server Analysis

An analysis of the best server in the coverage maps in Figure 16 reveals that a deployment of the NPN site at Saikeri to complement Safaricom's site at Kimuka is likely to enhance coverage in Zone A and improve connectivity. The best server coverage map indicates that Namelok's NPN site is best suited to address the coverage gaps left by Safaricom's Kimuka site in the valley closer to Saikeri. The brown colour in the best server analysis map in Figure 16 illustrates this. Conversely, the green section represents the coverage of Safaricom's site at Kimuka as the best server.

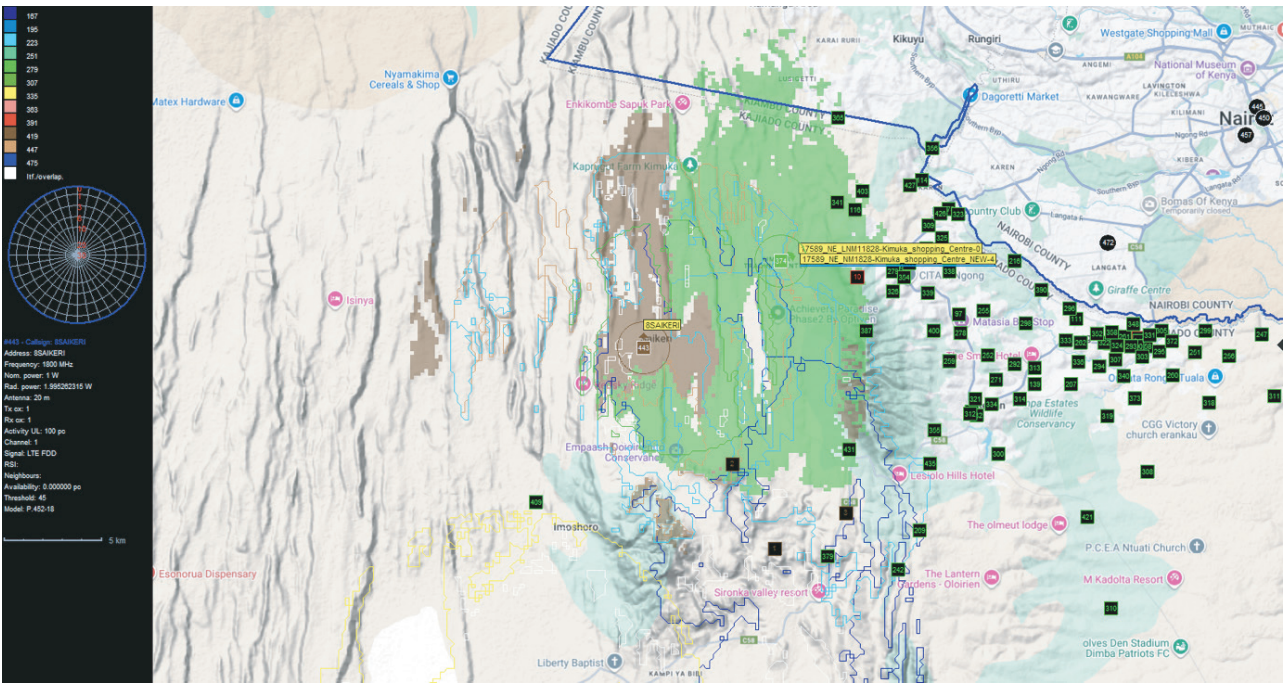


Figure 16: Zone-A Kimuka Best Server Coverage from Both Safaricom's LTE and Proposed Namelok NPN Site



## Present Coverage Analysis: Zone B-1 (KISAMIS-CORNER)

Table 2: Kisamis Corner Safaricom site 431 parameters

| " Site(s) Parameters                                                  | Safaricom Site 431 LTE (FDD)                                                 |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Power                                                                 | 3W                                                                           |
| Frequency                                                             | 1800 MHZ                                                                     |
| TX Gain                                                               | 15.40dBi                                                                     |
| EIRP                                                                  | 92.70885W                                                                    |
| TX losses                                                             | 0.5db                                                                        |
| Antenna Height                                                        | 45m                                                                          |
| TX/RX Bandwidth                                                       | 10MHZ                                                                        |
| Propagation Model                                                     | ITU-P542-18                                                                  |
| Technology                                                            | LTE FDD                                                                      |
| Sub Carrier Spacing                                                   | 15KHz                                                                        |
| Total RBs                                                             | 50                                                                           |
| Total Subcarriers                                                     | 600                                                                          |
| RB bandwidth                                                          | 180KHz                                                                       |
| Antenna Radiation                                                     | Isotropic                                                                    |
| Antenna Azimuth                                                       | 140°                                                                         |
| Antenna Tilt                                                          | 0°                                                                           |
| Activity Uplink                                                       | 100%                                                                         |
| Activity Downlink                                                     | 100%                                                                         |
| TX Clutter /RX Clutter                                                | Provided in HTZ Software as DEM (Digital Elevation/Terrain Model) Maps       |
| RX Threshold dBu                                                      | 45 *conversion of (-97dBm) to field strength 45dBμV/m                        |
| Coverage Threshold dBu                                                | 68.3 * addition of RX threshold (45. BμV/m)and additional losses (23dB)      |
| RSRP (Reference Signal Received Power) Receiver Sensitivity threshold | "-115 dBm                                                                    |
| KTBF (dBm) Thermal noise floor                                        | -97dBm                                                                       |
| C/I Requirement                                                       | -6.00 / -6.00                                                                |
| Height of RX antenna                                                  | 1.5m                                                                         |
| Cut off distance                                                      | 12km * Based on Communication Authority Max. Range in Rural areas guidelines |
| Minimum Coverage value dBu                                            | 30                                                                           |
| Wanted threshold                                                      | 45                                                                           |

## Zone B-1- Kisamis Corner Safaricom Site 431 Downlink Coverage Results

The downlink Coverage map from Safaricom's LTE site in Zone B-1 at Kisamis Corner shows good coverage and reception. Fewer coverage gaps are seen, especially towards the northwest heading to the valley closer to Saikeri. The same coverage Gap is consistent in Zone A's analysis. On the other hand, the eastern and southern side of the coverage map shows good coverage with RSRP coverage threshold above -85 in most areas. Ngong hills to the east still blocks the signal from Safaricom's LTE site at Kisamis Corner

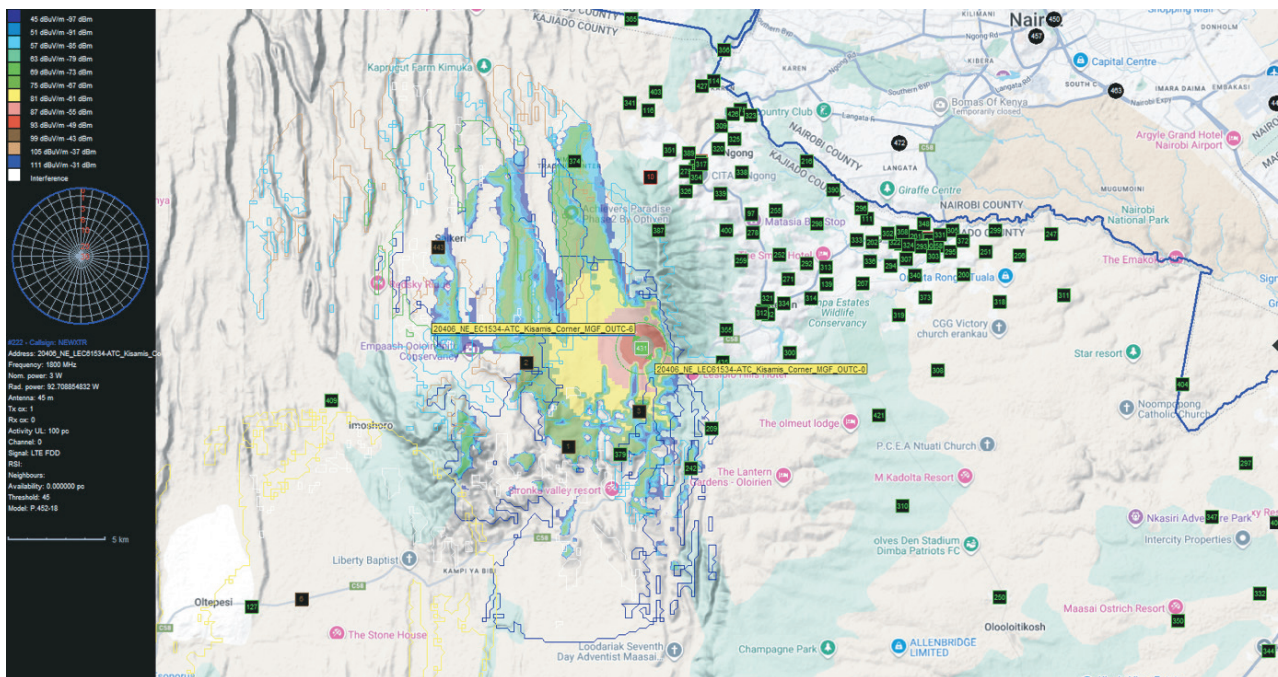


Figure 17: Zone B-1-Kisamis Corner Safaricom Site 431 LTE downlink coverage results

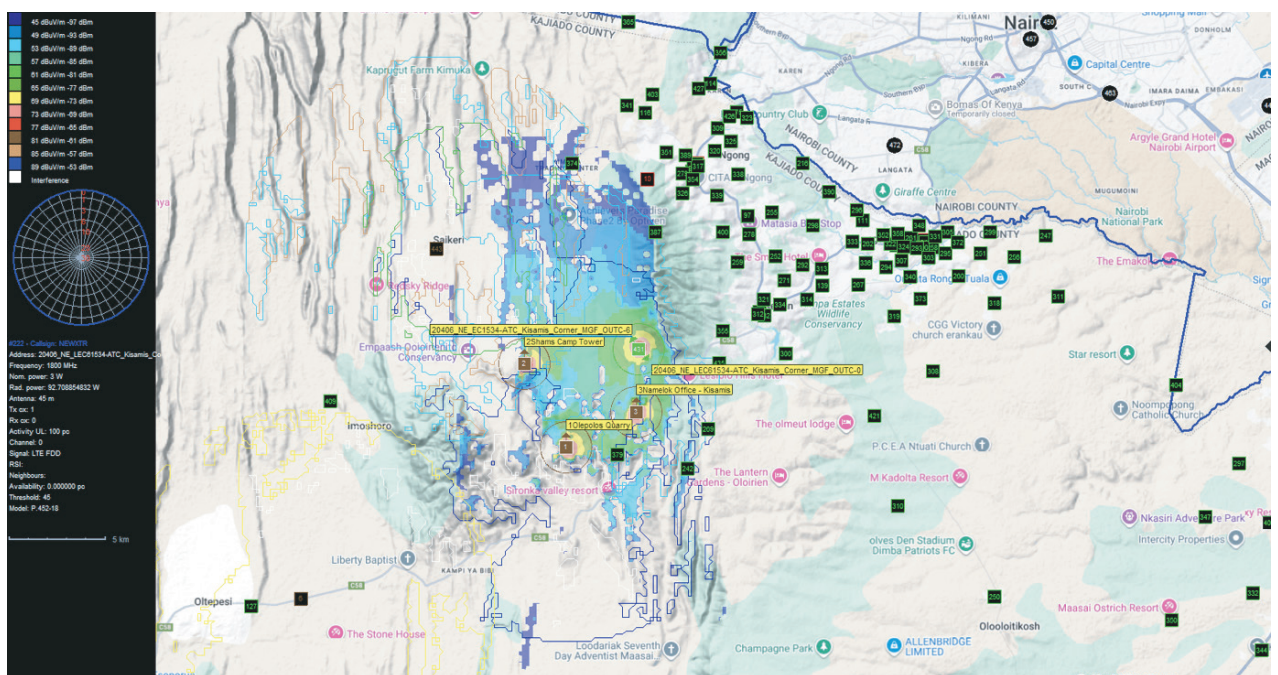


Figure 18: Zone B-1-Kisamis Corner Safaricom Site 431 LTE Uplink coverage results

The uplink coverage results indicate a similar trend to the downlink coverage results discussed earlier, except for a decrease in the RSRP Coverage Threshold. Certain sections to the north experience lower and weaker signals, with RSRP thresholds ranging from -89 dBm to -97 dBm. Conversely, the coverage gap in the west and north-western direction towards Saikeri widens in the uplink direction. While the southern region is relatively unaffected by the uplink, there is still a degree of signal weakness within the RSRP coverage threshold ranges of -77 dBm to -85 dBm.

### Kisamis Corner 3 Neighbouring NPN Sites: Shams Camp, Olepolos and Namelok Office

In Zone B-1, as shown in the coverage maps in Figures 15 and 16 above, there are three neighbouring Namelok community network sites within the vicinity of Safaricom Site 431. In this study, we use the three sites, Namelok Office, Olepolos and Shams Camp as potential sites for NPN deployment. We model the coverage of these sites using the parameters shown in Table 10.

| " Site(s) Parameters                                                  | 3NPN Sites Params: Sham's Camp, Olepolos and Namelok Office Kisamis NPN Sites LTE (FDD) |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Power                                                                 | 1W                                                                                      |
| Frequency                                                             | 1800 MHZ                                                                                |
| TX Gain                                                               | 3.5dBi                                                                                  |
| EIRP                                                                  | 1.995262W                                                                               |
| TX losses                                                             | 0.5dB                                                                                   |
| Antenna Height                                                        | 20m                                                                                     |
| TX/RX Bandwidth                                                       | 10MHZ                                                                                   |
| Propagation Model                                                     | ITU-P542-18                                                                             |
| Technology                                                            | LTE FDD                                                                                 |
| Sub Carrier Spacing                                                   | 15KHz                                                                                   |
| Total RBs                                                             | 50                                                                                      |
| Total Subcarriers                                                     | 600                                                                                     |
| RB bandwidth                                                          | 180KHz                                                                                  |
| Antenna Radiation                                                     | Isotropic                                                                               |
| Antenna Tilt                                                          | 0°                                                                                      |
| Activity Uplink                                                       | 100%                                                                                    |
| Activity Downlink                                                     | 100%                                                                                    |
| TX Clutter /RX Clutter                                                | Provided in HTZ Software as DEM (Digital Elevation/Terrain Model) Maps                  |
| RX Threshold dBu                                                      | 45 *conversion of (-97dBm) to field strength 45dBμV/m                                   |
| Coverage Threshold dBu                                                | 68.3 * addition of RX threshold (45. BμV/m) and additional losses (23dB)                |
| RSRP (Reference Signal Received Power) Receiver Sensitivity threshold | "-115 dBm                                                                               |
| KTBF (dBm) Thermal noise floor                                        | -97dBm                                                                                  |
| C/I Requirement                                                       | -6.00 / -6.00                                                                           |
| Height of RX antenna                                                  | 1.5m                                                                                    |
| Cut off distance                                                      | 12km * Based on Communication Authority Max. Range in Rural areas guidelines            |
| Minimum Coverage value dBU                                            | 30                                                                                      |
| Wanted threshold                                                      | 45                                                                                      |

Table 3: Kisamis corner 3 Namelok NPN sites Parameters



## Zone B-1- Kisamis Corner Safaricom Site 431 Downlink Coverage Results

The downlink Coverage map from Safaricom's LTE site in Zone B-1 at Kisamis Corner shows good coverage and reception. Fewer coverage gaps are seen, especially towards the northwest heading to the valley closer to Saikeri. The same coverage Gap is consistent in Zone A's analysis. On the other hand, the eastern and southern side of the coverage map shows good coverage with RSRP coverage threshold above -85 in most areas. Ngong hills to the east still blocks the signal from Safaricom's LTE site at Kisamis Corner

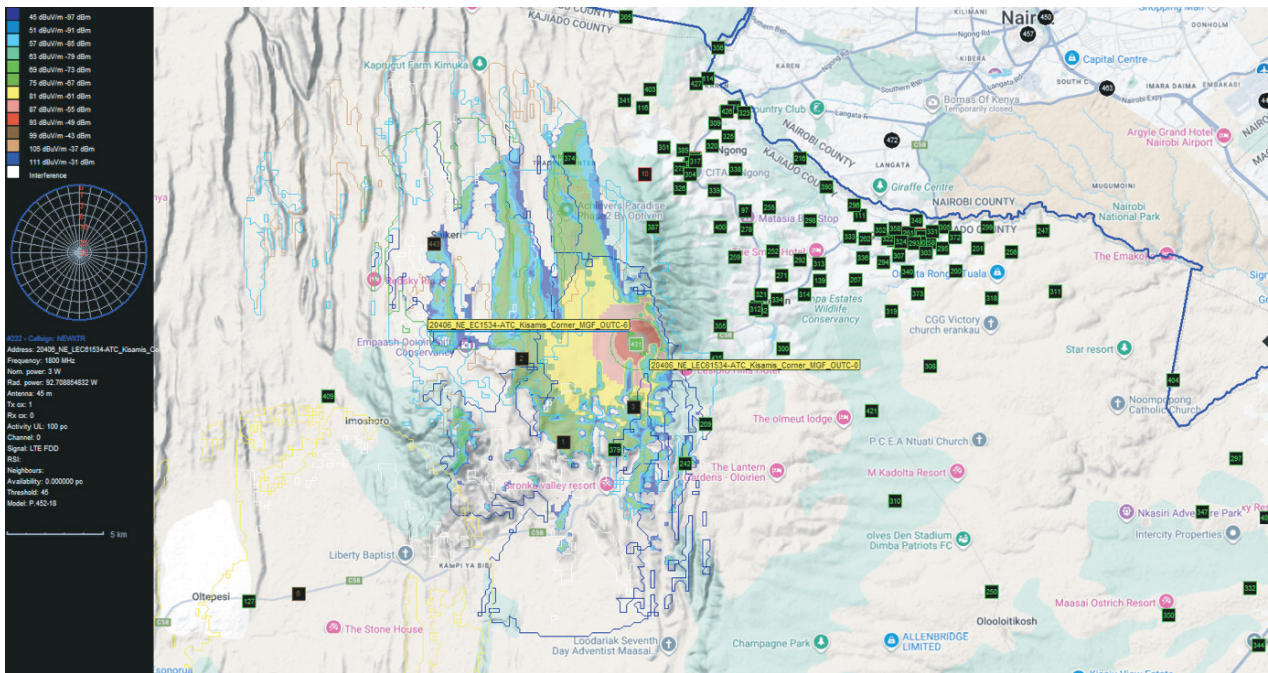


Figure 17: Zone B-1-Kisamis Corner Safaricom Site 431 LTE downlink coverage results

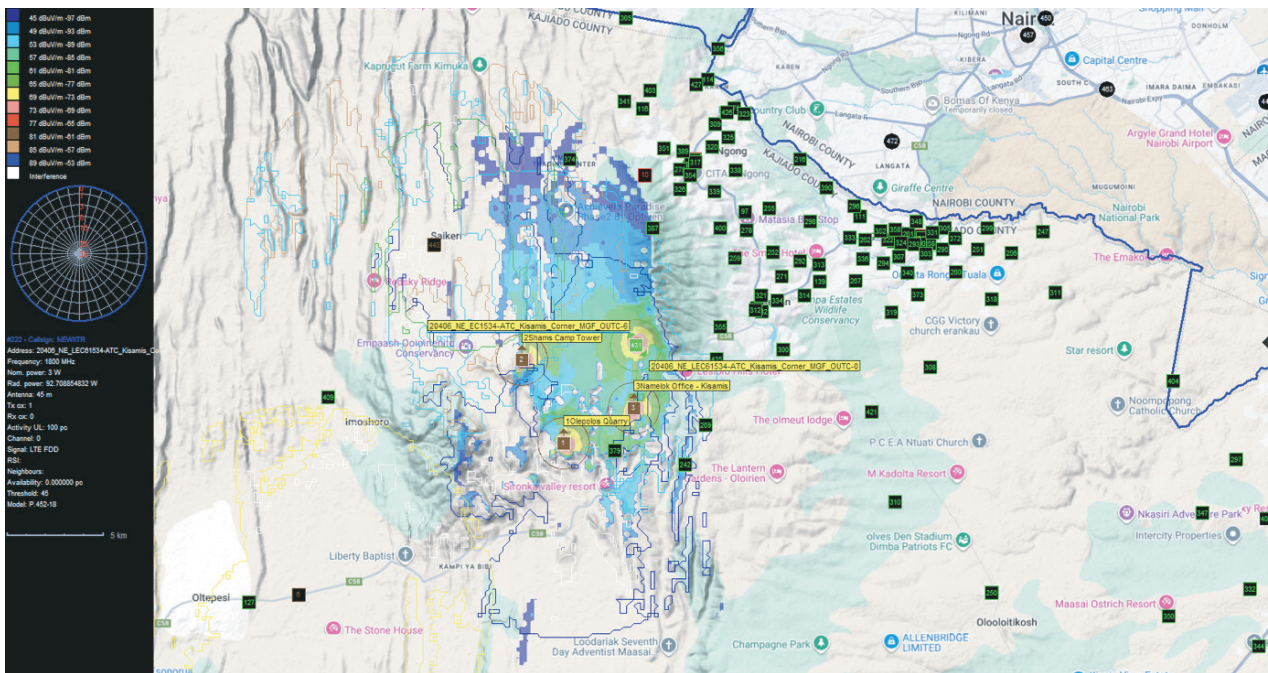


Figure 18: Zone B-1-Kisamis Corner Safaricom Site 431 LTE Uplink coverage results

The uplink coverage results indicate a similar trend to the downlink coverage results discussed earlier, except for a decrease in the RSRP Coverage Threshold. Certain sections to the north experience lower and weaker signals, with RSRP thresholds ranging from -89 dBm to -97 dBm. Conversely, the coverage gap in the west and north-western direction towards Saikeri widens in the uplink direction. While the southern region is relatively unaffected by the uplink, there is still a degree of signal weakness within the RSRP coverage threshold ranges of -77 dBm to -85 dBm.

## Kisamis Corner 3 Neighbouring NPN Sites: Shams Camp, Olepolos and Namelok Office

In Zone B-1, as shown in the coverage maps in Figures 15 and 16 above, there are three neighbouring Namelok community network sites within the vicinity of Safaricom Site 431. In this study, we use the three sites, Namelok Office, Olepolos and Shams Camp as potential sites for NPN deployment. We model the coverage of these sites using the parameters shown in Table 10.

| " Site(s) Parameters                                                  | 3NPN Sites Params: Sham's Camp, Olepolos and Namelok Office Kisamis NPN Sites LTE (FDD) |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Power                                                                 | 1W                                                                                      |
| Frequency                                                             | 1800 MHZ                                                                                |
| TX Gain                                                               | 3.5dBi                                                                                  |
| EIRP                                                                  | 1.995262W                                                                               |
| TX losses                                                             | 0.5dB                                                                                   |
| Antenna Height                                                        | 20m                                                                                     |
| TX/RX Bandwidth                                                       | 10MHZ                                                                                   |
| Propagation Model                                                     | ITU-P542-18                                                                             |
| Technology                                                            | LTE FDD                                                                                 |
| Sub Carrier Spacing                                                   | 15KHz                                                                                   |
| Total RBs                                                             | 50                                                                                      |
| Total Subcarriers                                                     | 600                                                                                     |
| RB bandwidth                                                          | 180KHz                                                                                  |
| Antenna Radiation                                                     | Isotropic                                                                               |
| Antenna Tilt                                                          | 0°                                                                                      |
| Activity Uplink                                                       | 100%                                                                                    |
| Activity Downlink                                                     | 100%                                                                                    |
| TX Clutter /RX Clutter                                                | Provided in HTZ Software as DEM (Digital Elevation/Terrain Model) Maps                  |
| RX Threshold dBu                                                      | 45 *conversion of (-97dBm) to field strength 45dBμV/m                                   |
| Coverage Threshold dBu                                                | 68.3 * addition of RX threshold (45. BμV/m) and additional losses (23dB)                |
| RSRP (Reference Signal Received Power) Receiver Sensitivity threshold | -115 dBm                                                                                |
| KTBF (dBm) Thermal noise floor                                        | -97dBm                                                                                  |
| C/I Requirement                                                       | -6.00 / -6.00                                                                           |
| Height of RX antenna                                                  | 1.5m                                                                                    |
| Cut off distance                                                      | 12km * Based on Communication Authority Max. Range in Rural areas guidelines            |
| Minimum Coverage value dBU                                            | 30                                                                                      |
| Wanted threshold                                                      | 45                                                                                      |

Table 3: Kisamis corner 3 Namelok NPN sites Parameters



## Zone B-1- Kisamis Corner Shams OLEPOLOS NPN Site Downlink and UPLINK Coverage Results

The Olepolos NPN downlink coverage results indicate a signal concentration towards the east, with obstructions from the Ngong hills. This signal is likely to overlap with the signals from Safaricom Site 431, providing extended coverage towards the east.

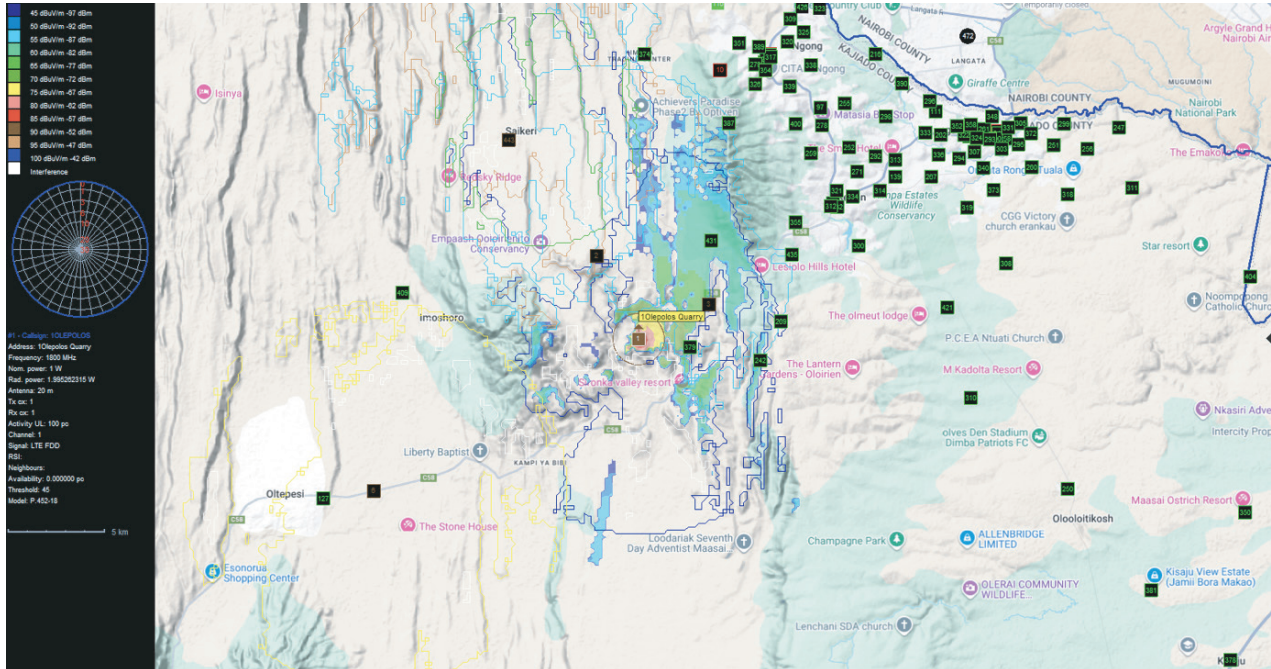


Figure 19: Zone B-1-Kisamis Corner Olepolos NPN site downlink coverage results

The Olepolos NPN downlink coverage results indicate a signal concentration towards the east, with obstructions from the Ngong hills. This signal is likely to overlap with the signals from Safaricom Site 431, providing extended coverage towards the east.

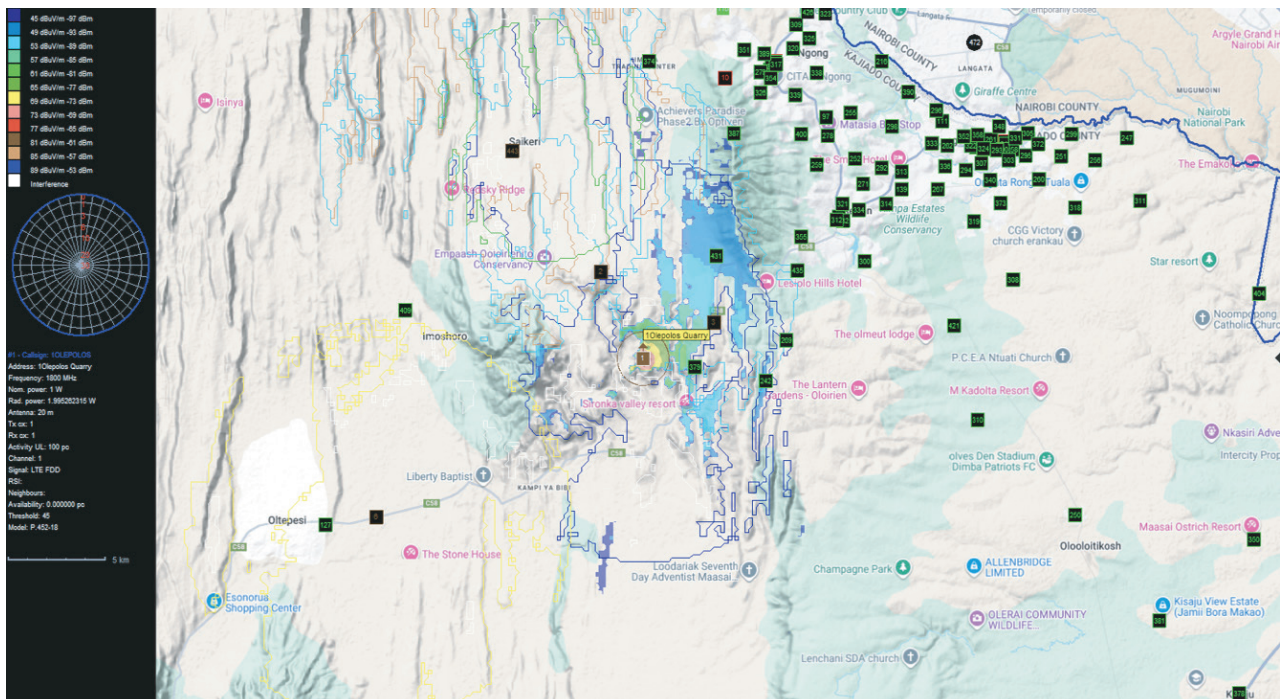


Figure 20: Zone B-1-Kisamis Corner Olepolos NPN site Uplink coverage results



The Olepolos NPN coverage uplink results exhibit a consistent pattern with the downlink results. The concentration of acceptable receiver uplink signals is oriented towards the eastern region, specifically towards the Ngong hills. However, it is noteworthy that the RSRP Coverage Threshold values are significantly lower within most of the coverage area, ranging from -89 dBm to -97 dBm.

**Zone B-1- Kisamis Corner Shams Camp Tower NPN Site Downlink and Uplink Coverage Results**

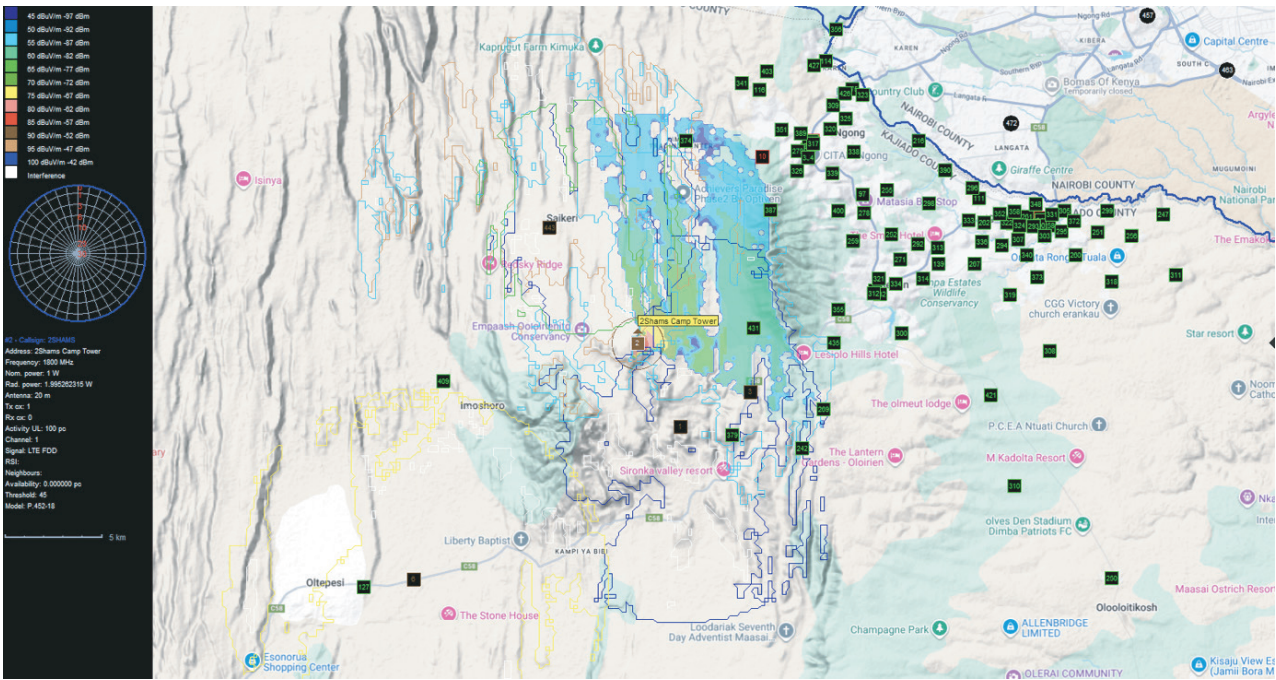


Figure 21: Zone B-1-Kisamis Corner Shams Camp NPN site Downlink coverage results

Sham’s camp tower NPN downlink coverage results show satisfactory coverage with a potential to bridge the coverage gap left by Safaricom’s Site 431 towards the north, as illustrated in Figure 21. The received signal strength indicator (RSRP) falls within the acceptable and reliable RSRP Coverage Threshold range of -77 dBm to -85 dBm within the coverage area of Sham’s camp. However, coverage towards the south is limited.

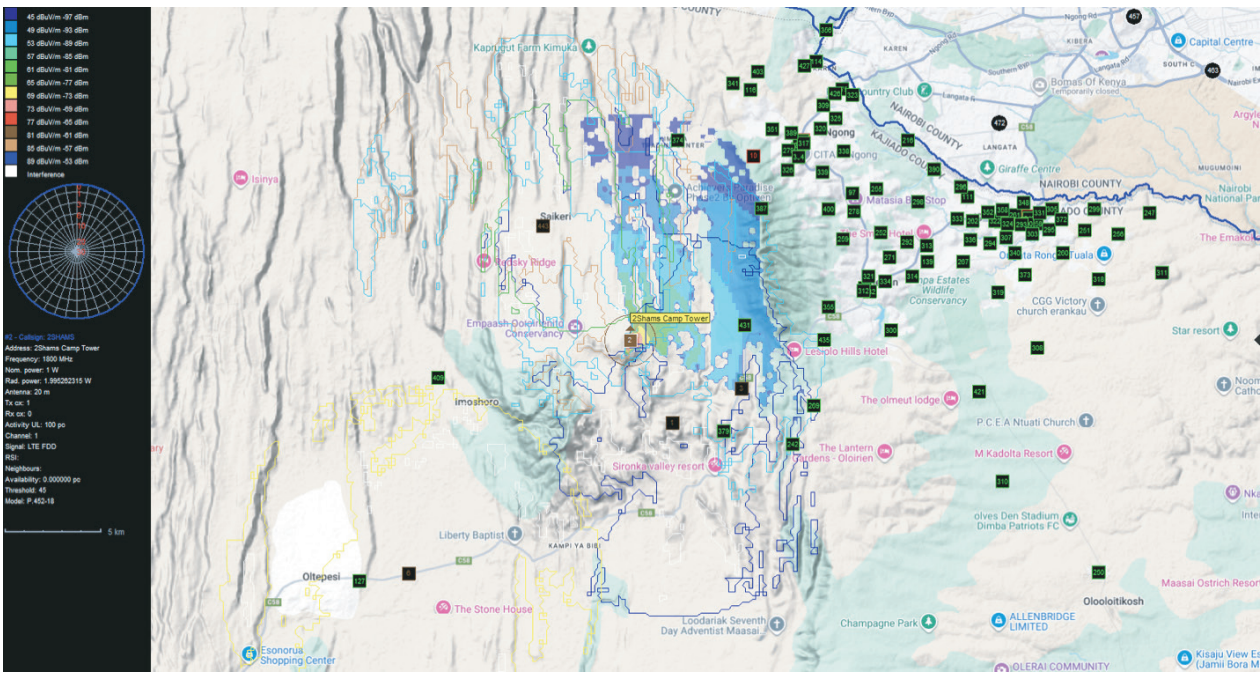


Figure 22: Zone B-1-Kisamis Corner Shams Camp NPN site Uplink coverage results

Sham's camp NPN coverage uplink results exhibit a consistent pattern with the downlink results in Figure 222. The concentration of acceptable receiver uplink signals can still complement Safaricom's Site 431 towards the north. However, the RSRP Coverage Threshold values are significantly lower within much of the coverage area, ranging from -89 dBm to -97 dBm. Coverage towards the south is still limited.

## Zone B-1- Kisamis Corner Namelok Kisamis Office NPN Site Downlink and Uplink Coverage Results

Namelok's office NPN site primarily covers the western and eastern regions, with notable gaps in the northern area and a limited coverage presence in the southern region. In comparison to Safaricom's Site 431 coverage area, as depicted in Figures 23 and 24, Namelok's Office site signals are likely to overlap and be overshadowed by the coverage of Safaricom's Site 431.

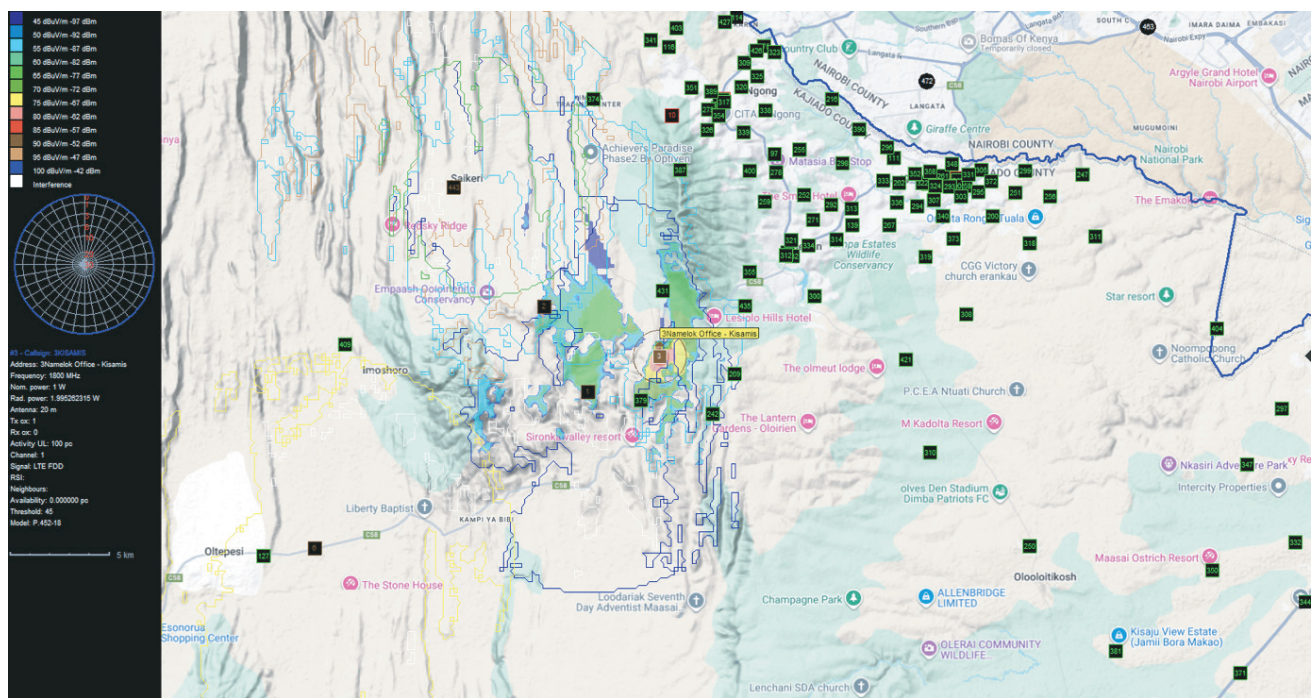
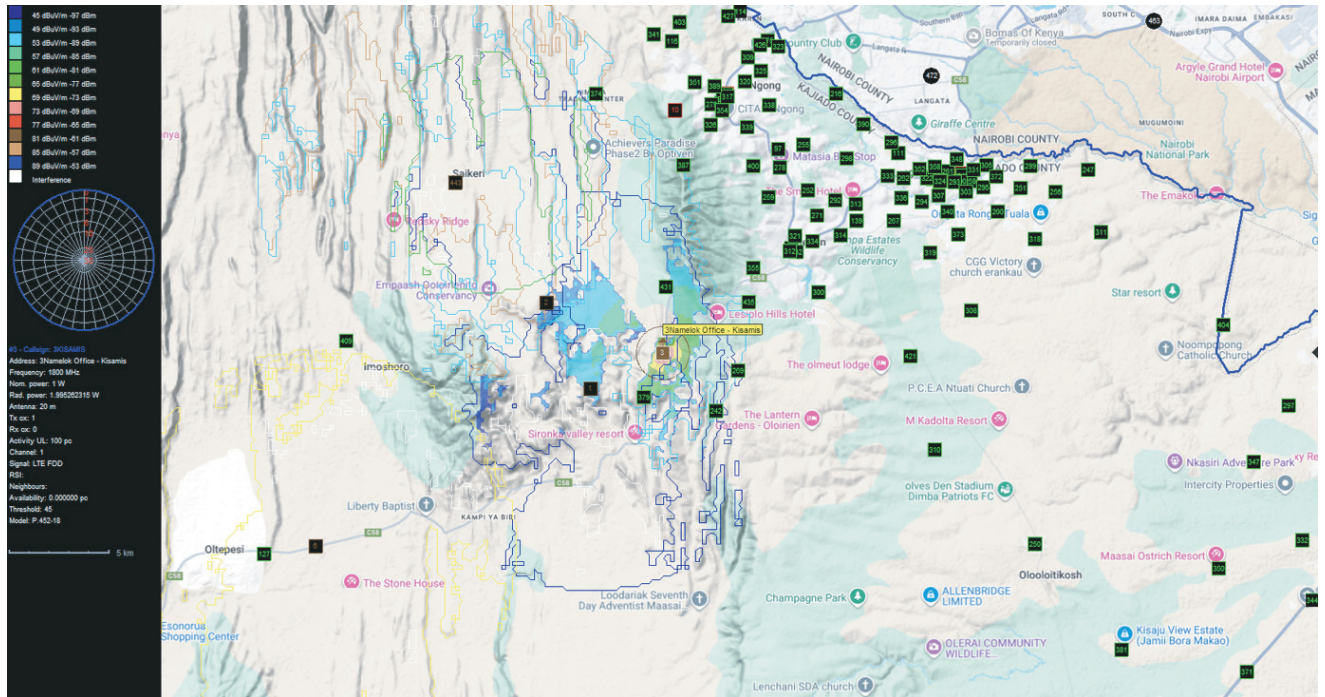


Figure 23: Zone B-1-Kisamis Corner Namelok Office NPN site Downlink coverage results



Figure 24: Zone B-1-Kisamis Corner Namelok Office NPN site Uplink coverage results



The uplink coverage in Zone B-1- Kisamis Corner Namelok Kisamis Office by the NPN shows a similar trend to the downlink coverage, with a lower RSRP Coverage Threshold. This signal is equally likely to overlap and be overshadowed by the coverage of Safaricom's Site 431.

## Zone B-1- Kisamis Corner Composite Coverage Downlink and Uplink Results

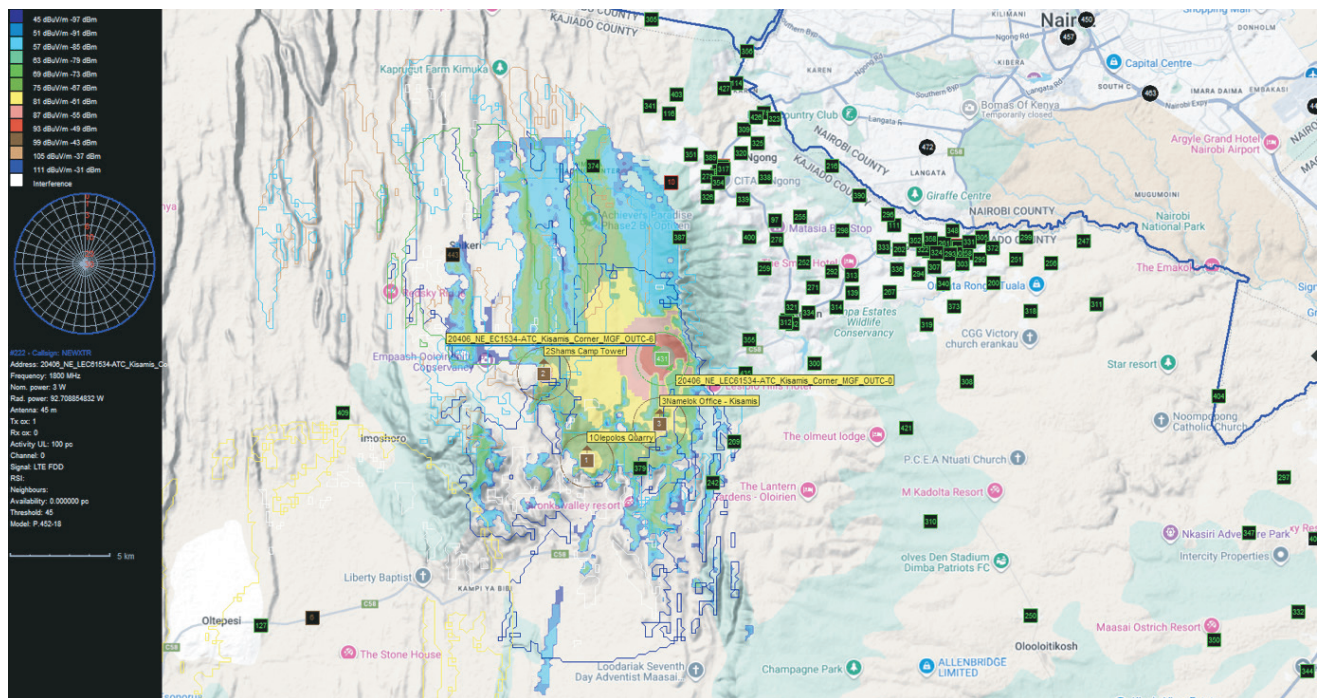


Figure 25: Zone B-1 Kisamis Corner Composite Coverage Downlink



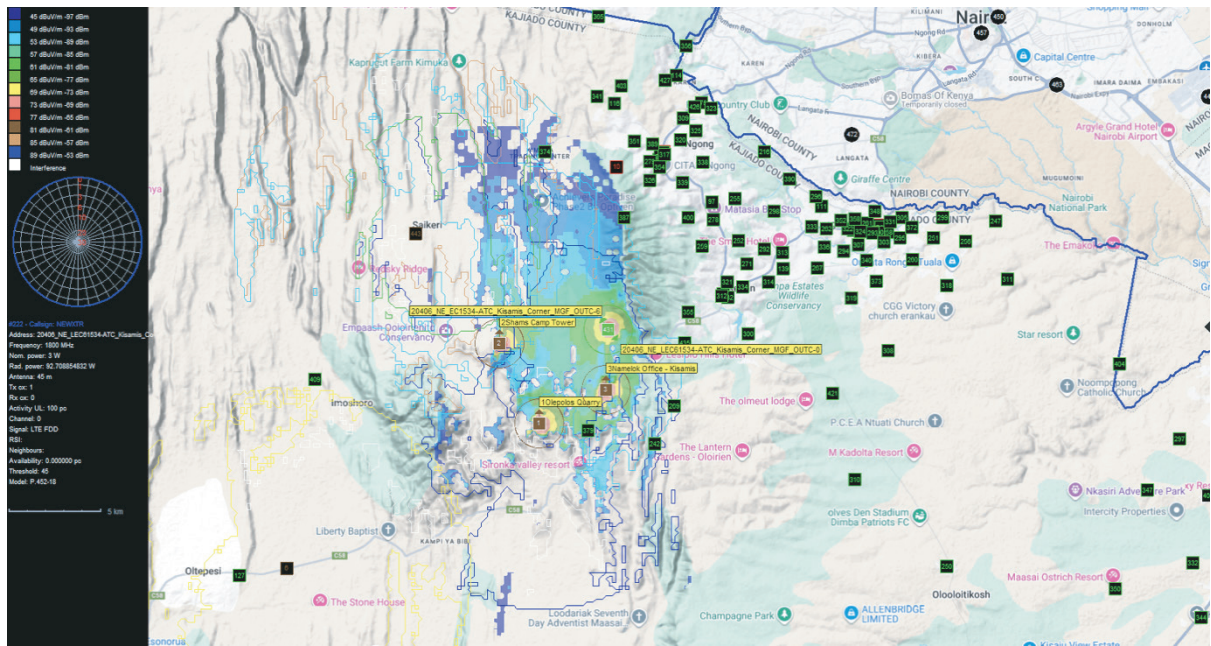


Figure 26: Zone B-1 Kisamis Corner Composite Coverage Uplink

The composite coverage maps of the downlink and uplink for both the three NPNs sites at Sham's camp, Oleoplos, and Namelok Office, as well as Safaricom's Site 431 in Zone B-1- Kisamis Corner, are presented in Figures 25 and 26. These maps illustrate an area where NPNs and Mobile Network Operators (MNOs) can converge, resulting in nearly complete coverage with minimal gaps. However, interference between these networks poses a potential risk and warrants further investigation. The potential of this interference is examined in the subsequent section dedicated to Interference Analysis in this report.

## Zone B-1- Kisamis Corner Best Server Analysis Coverage Results

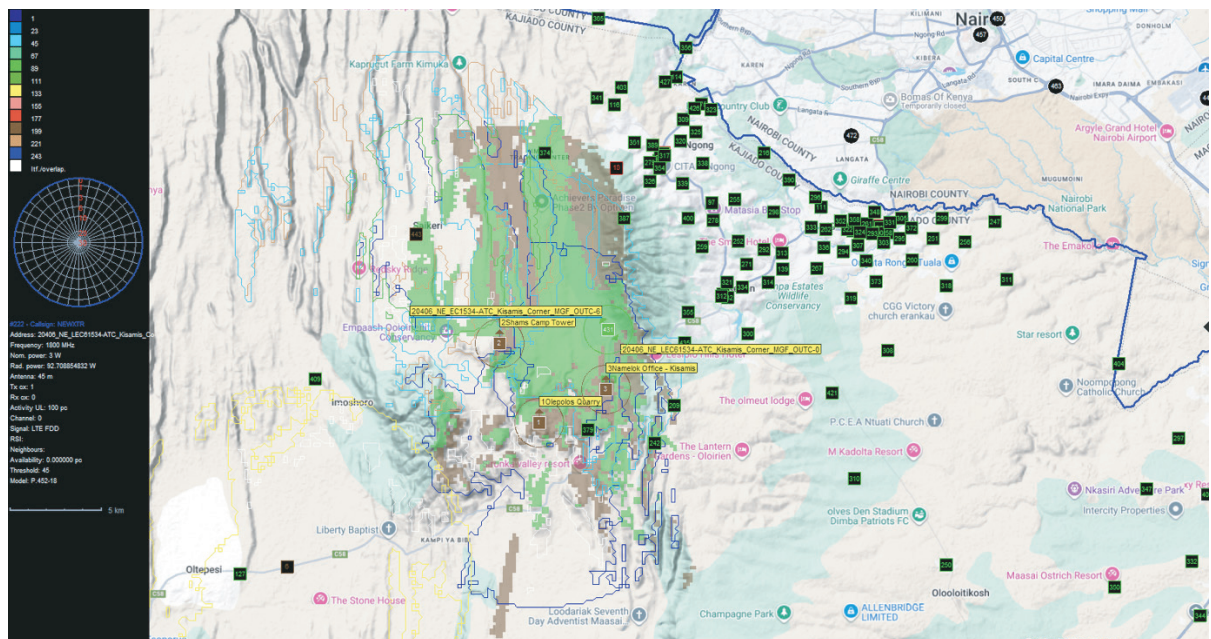


Figure 27: Zone B-1 Kisamis Corner Best Server Coverage Map

Figure 27 presents the best server coverage map, indicating that the northwest region near Saikeri, previously identified as a coverage gap by Safaricom's Site 431, is likely to be adequately covered and served by the NPN at Sham's camp. A portion of the reliable signals from Sham's camp NPN can extend to the periphery of Ngong Hills to the east of Zone B-1, Kisamis Corner. The NPNs situated at Olepolos and Namelok Office are most suitable for covering areas within the southern region of Zone B-1. This analysis underscores the ongoing presence of potential interference, which will be further explored in the Interference Analysis section of this report.

## Zone B-2- Kisamis Market Coverage Analysis

Table 4: Zone B-2 Kisamis Market Safaricom site 379 parameters

| " Site(s) Parameters                                                  | Safaricom Site 379 LTE Site 160 (FDD)                                        |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Power                                                                 | 3W                                                                           |
| Frequency                                                             | 1800 MHZ                                                                     |
| TX Gain                                                               | 15.70dBi                                                                     |
| EIRP                                                                  | 99.33933W                                                                    |
| TX losses                                                             | 0.5db                                                                        |
| Antenna Height                                                        | 34m                                                                          |
| TX/RX Bandwidth                                                       | 10MHZ                                                                        |
| Propagation Model                                                     | ITU-P542-18                                                                  |
| Technology                                                            | LTE FDD                                                                      |
| Sub Carrier Spacing                                                   | 15KHz                                                                        |
| Total RBs                                                             | 50                                                                           |
| Total Subcarriers                                                     | 600                                                                          |
| RB bandwidth                                                          | 180KHz                                                                       |
| Antenna Radiation                                                     | Isotropic                                                                    |
| Antenna Azimuth                                                       | 0°                                                                           |
| Antenna Tilt                                                          | 0°                                                                           |
| Activity Uplink                                                       | 100%                                                                         |
| Activity Downlink                                                     | 100%                                                                         |
| TX Clutter /RX Clutter                                                | Provided in HTZ Software as DEM (Digital Elevation/Terrain Model) Maps       |
| RX Threshold dBu                                                      | 45 *conversion of (-97dBm) to field strength 45dBμV/m                        |
| Coverage Threshold dBu                                                | 68.3 * addition of RX threshold (45. BμV/m)and additional losses (23dB)      |
| RSRP (Reference Signal Received Power) Receiver Sensitivity threshold | -115 dBm                                                                     |
| KTBF (dBm) Thermal noise floor                                        | -97dBm                                                                       |
| C/I Requirement                                                       | -6.00 / -6.00                                                                |
| Height of RX antenna                                                  | 1.5m                                                                         |
| Cut off distance                                                      | 12km * Based on Communication Authority Max. Range in Rural areas guidelines |
| Minimum Coverage value dBu                                            | 30                                                                           |
| Wanted threshold                                                      | 45                                                                           |



## Zone B-2- Kisamis Market Safaricom LTE

Site 379 Downlink and Uplink Coverage Results:

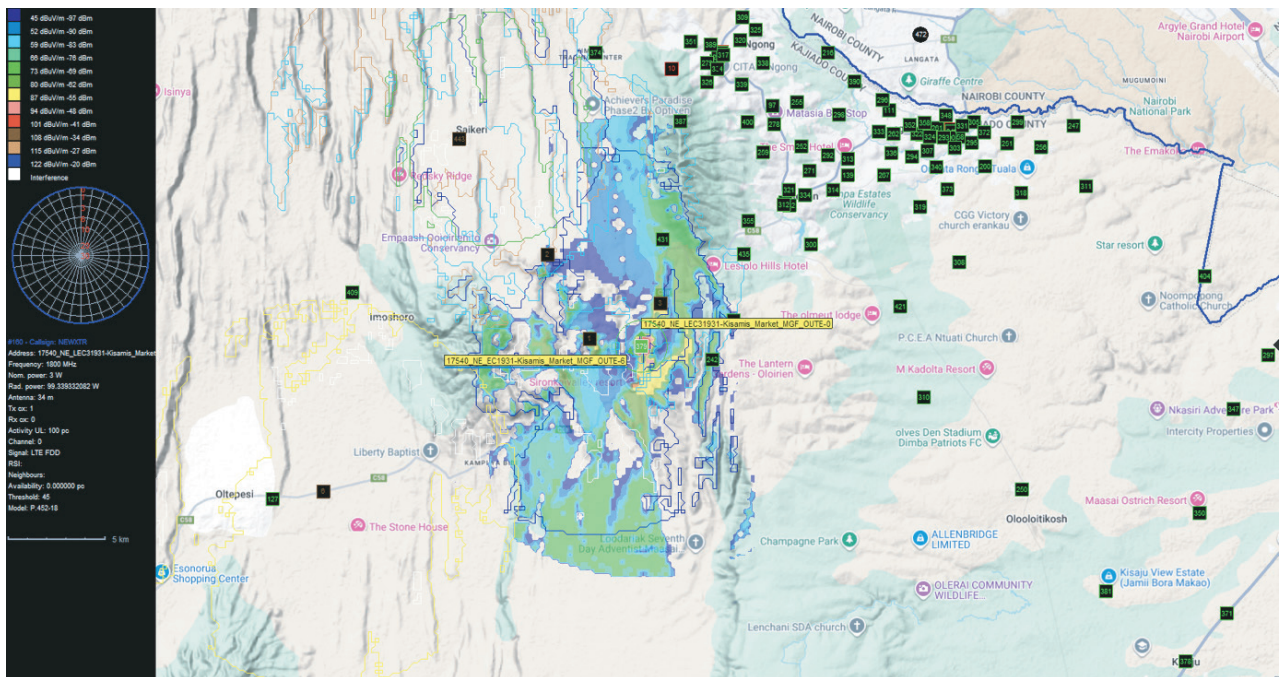


Figure 28: Zone-B- 2 Kisamis Market Safaricom LTE Site 379 Downlink Coverage Results

The downlink coverage by Safaricom LTE Site 379 in Zone B-2- Kisamis Market extends southward, where Safaricom's Site 431 lacks coverage. This strategic positioning allows for the provision of adequate coverage beyond Loodariak Seventh Day Adventist Church, offering fair and reliable signals within the coverage threshold range of -77 dBm to -85 dBm. However, it is observed that certain gaps still exist in this isolated coverage plot of Safaricom LTE Site 379 within Zone B-2- Kisamis Market.

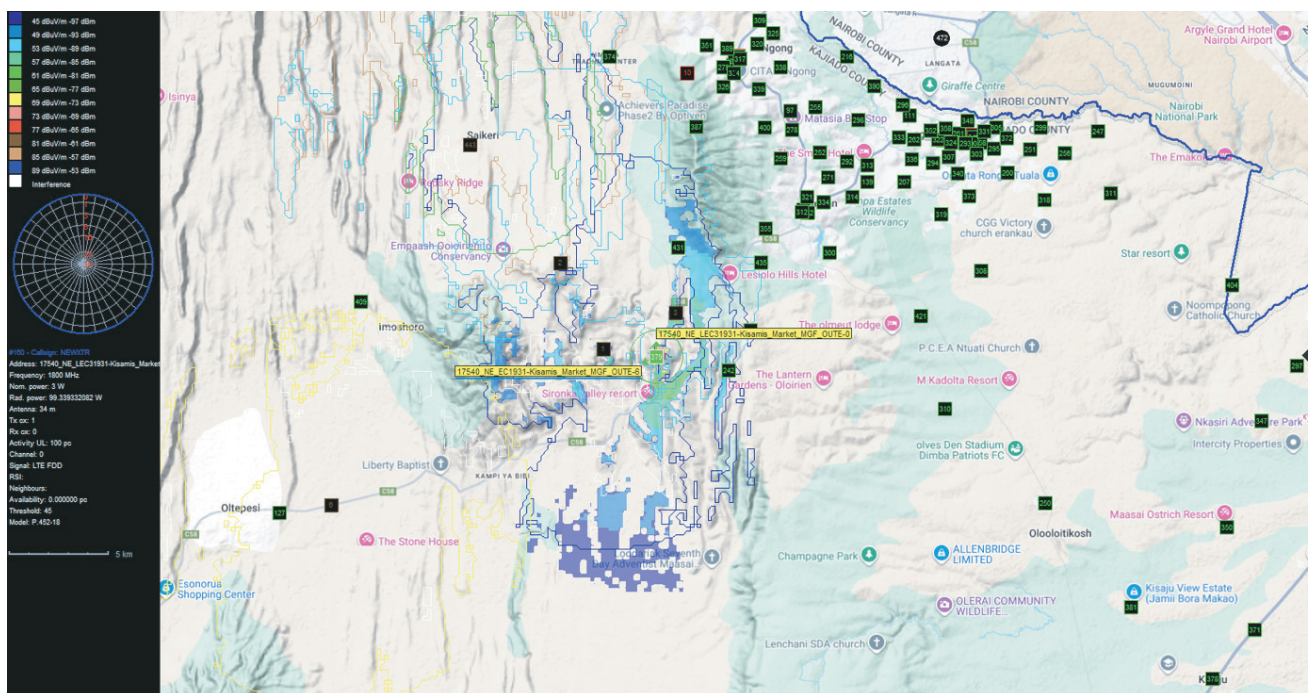


Figure 29: Zone-B- 2 Kisamis Market Safaricom LTE Site 379 Uplink Coverage Results



The uplink coverage in Zone B-2, Kisamis Market, covered by Safaricom's Site 379, presents a contrasting scenario. While the signal experiences a notable degradation in the southern region, the coverage gaps in uplink transmissions also widen. These coverage gaps extend to the northwest region, to include the area covered by the Olepolos quarry NPN site and Sham's camp coverage area. Notably, there are evident uplink coverage gaps in these areas within Zone B-2, Kisamis Market.

## Kisamis Market Site and 3 Neighbouring NPN Sites: Shams Camp, Olepolos and Namelok Office -- Parameters and Results

In this section, we do not present the coverage maps of the three NPN sites in Zone B-2- Kisamis Market. This is because for the three NPN sites: Shams Camp, Olepolos and Namelok Office, the coverage parameters are the same as what is shown in Table 9. Consequently, the coverage maps for these sites are similar to what is already shown in Figures 17, 19, 21 in the downlink direction and Figures 18, 20, and 22 in the uplink. Therefore, we proceed to analyse the composite coverage and the best server coverage maps in the next subsection.

## Zone B-2- Kisamis Market Downlink and Uplink Composite Coverage Maps Results

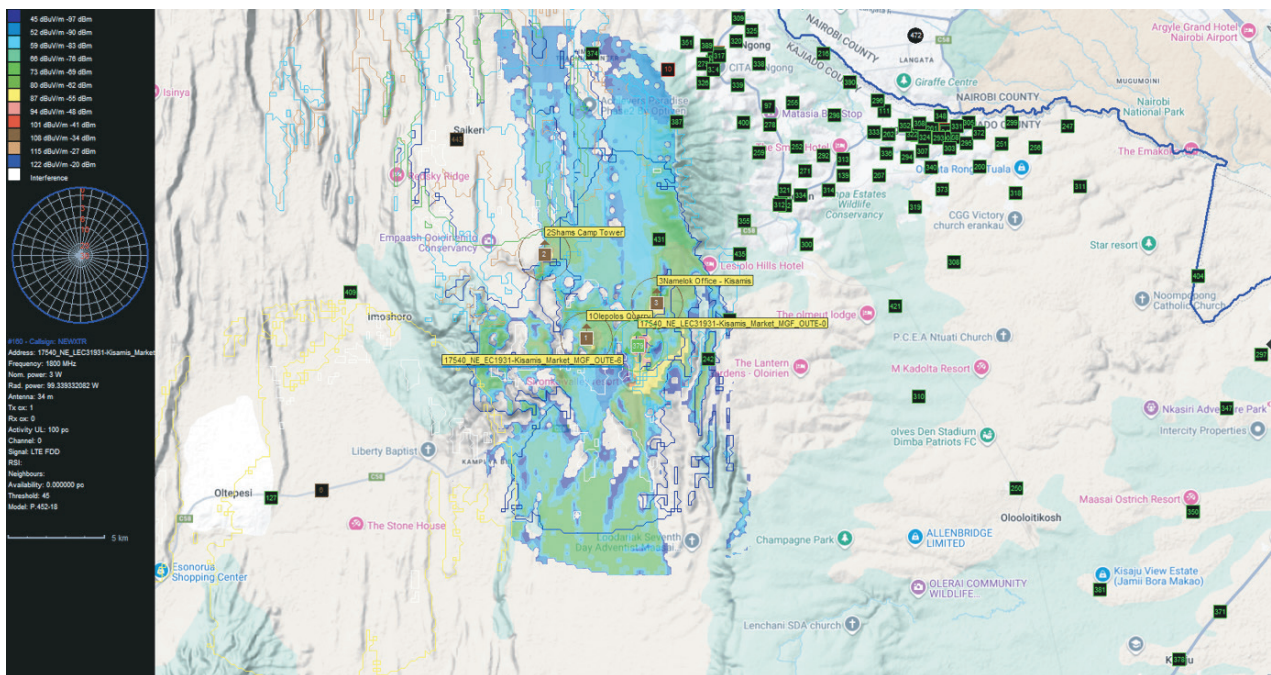
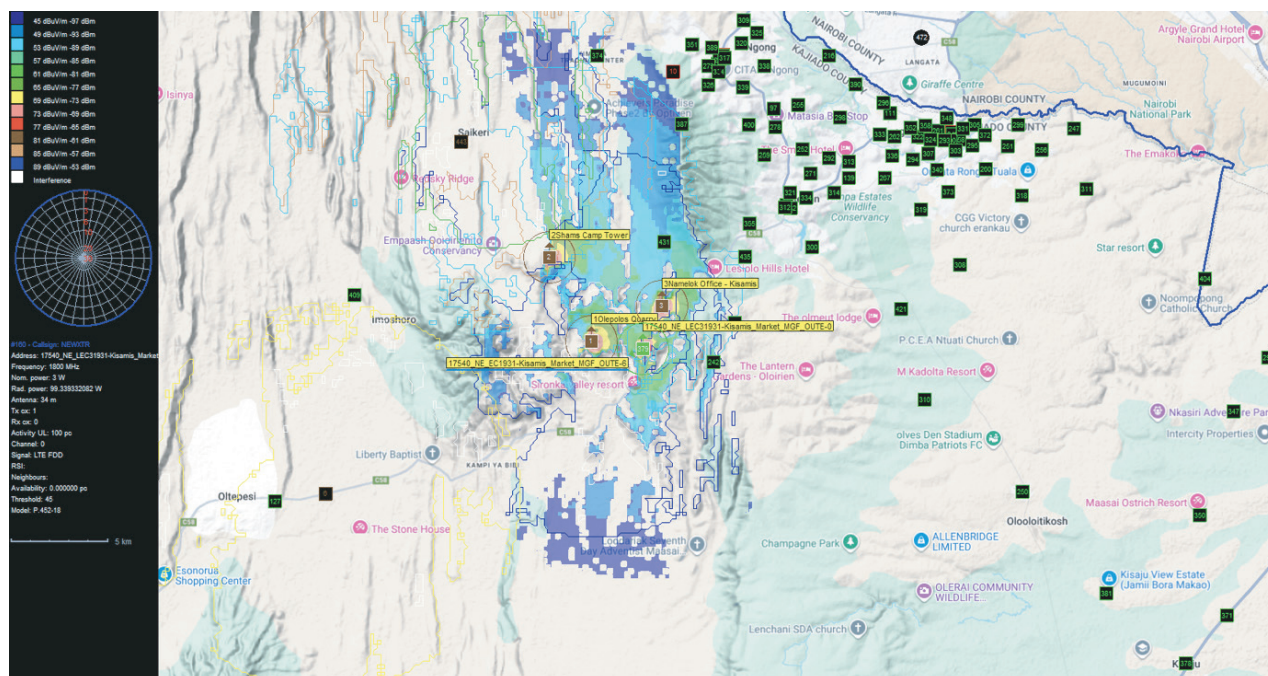


Figure 30: Zone-B- 2 Kisamis Market Downlink Composite Coverage Results

Figures 30 and 31 present composite coverage maps for the three NPNs at Sham's camp, Oleoplos, and Namelok Office, as well as Safaricom's Site 379 in Zone B-2-Kisamis Market. These maps depict an area where NPNs and Mobile Network Operators (MNOs) can converge, providing nearly complete coverage with minimal gaps. In comparison to Zone B-1, Kisamis Corner, this coverage extends further south, with some weak signal extending into areas covered by the Loodariak Seventh Day Adventist church.

Despite the composite coverage map in Zone B-2 showing similar coverage trend to the composite coverage map in Zone B-1, Zone B-2-Kisamis Market coverage map reveals some obvious coverage gaps, particularly in the south after the Sironka Valley resort. This valley is potentially not covered by either the MNO or when either of the Namelok NPNs is deployed. However, interference between these networks in the covered regions, both in the uplink and downlink, poses a potential risk and necessitates further investigation. The potential of this interference is examined in the subsequent section dedicated to Interference Analysis.

Figure 31: Zone-B- 2 Kisamis Market Uplink Composite Coverage



## Zone B-2- Kisamis Market Best Server Coverage Map Results

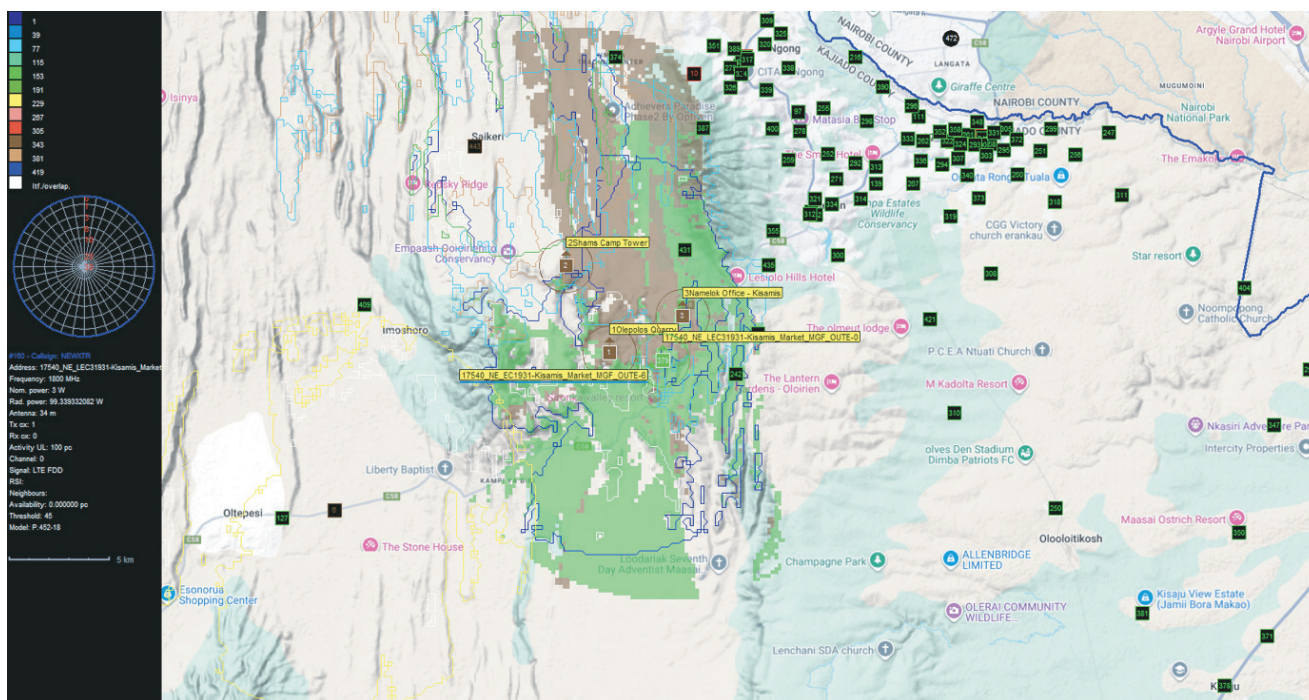


Figure 32: Zone-B- 2 Kisamis Market Best Server Coverage Results



Figure 32 presents comparable best sever coverage results to Figure 25, which illustrates the coverage of Safaricom's Site 431 in relation to the three NPNs situated in Zone B-1, Kisamis Corner. However, in Zone B-2-Kisamis Market, the three NPNs operating under a simulated scenario against Safaricom's Site 379 exhibit enhanced sever coverage extending to the southern region, predominantly by Safaricom's Site 379. The northwest area near Saikeri, previously identified as a coverage gap by Safaricom's Site 431, is likely to be adequately covered and served by the NPN at Sham's camp. A portion of the reliable signals from Sham's camp NPN can extend to the periphery of Ngong Hills to the east of Zone B-2-Kisamis Market. The NPNs at Olepolos and Namelok Office are suitable for covering areas within the central and eastern regions of Zone B-2-Kisamis Market. This analysis underscores the persistent presence of potential interference, which will be further analysed in the Interference Analysis section of this report.

## Zone C Oltepesi Tinga Coverage Analysis

| " Site(s) Parameters                                                  | Safaricom Site 127 LTE (FDD)                                                 |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Power                                                                 | 3W                                                                           |
| Frequency                                                             | 1800 MHZ                                                                     |
| TX Gain                                                               | 18.44dBi                                                                     |
| EIRP                                                                  | 186.6901W                                                                    |
| TX losses                                                             | 0.5db                                                                        |
| Antenna Height                                                        | 34.2m                                                                        |
| TX/RX Bandwidth                                                       | 10MHZ                                                                        |
| Propagation Model                                                     | ITU-P542-18                                                                  |
| Technology                                                            | LTE FDD                                                                      |
| Sub Carrier Spacing                                                   | 15KHz                                                                        |
| Total RBs                                                             | 50                                                                           |
| Total Subcarriers                                                     | 600                                                                          |
| RB bandwidth                                                          | 180KHz                                                                       |
| Antenna Radiation                                                     | Isotropic                                                                    |
| Antenna Azimuth                                                       | 0°                                                                           |
| Antenna Tilt                                                          | 0°                                                                           |
| Activity Uplink                                                       | 100%                                                                         |
| Activity Downlink                                                     | 100%                                                                         |
| TX Clutter /RX Clutter                                                | Provided in HTZ Software as DEM (Digital Elevation/Terrain Model) Maps       |
| RX Threshold dBu                                                      | 45 *conversion of (-97dBm) to field strength 45dBμV/m                        |
| Coverage Threshold dBu                                                | 68.3 * addition of RX threshold (45. BμV/m)and additional losses (23dB)      |
| RSRP (Reference Signal Received Power) Receiver Sensitivity threshold | "-115 dBm                                                                    |
| KTBF (dBm) Thermal noise floor                                        | -97dBm                                                                       |
| C/I Requirement                                                       | -6.00 / -6.00                                                                |
| Height of RX antenna                                                  | 1.5m                                                                         |
| Cut off distance                                                      | 12km * Based on Communication Authority Max. Range in Rural areas guidelines |
| Minimum Coverage value dBu                                            | 30                                                                           |
| Wanted threshold                                                      | 45                                                                           |

Table 5: Zone C Oltepesi Tinga Safaricom Site 127 parameters



## Zone C Oltepesi Tinga Safaricom Site 127 Downlink and Uplink Coverage Results

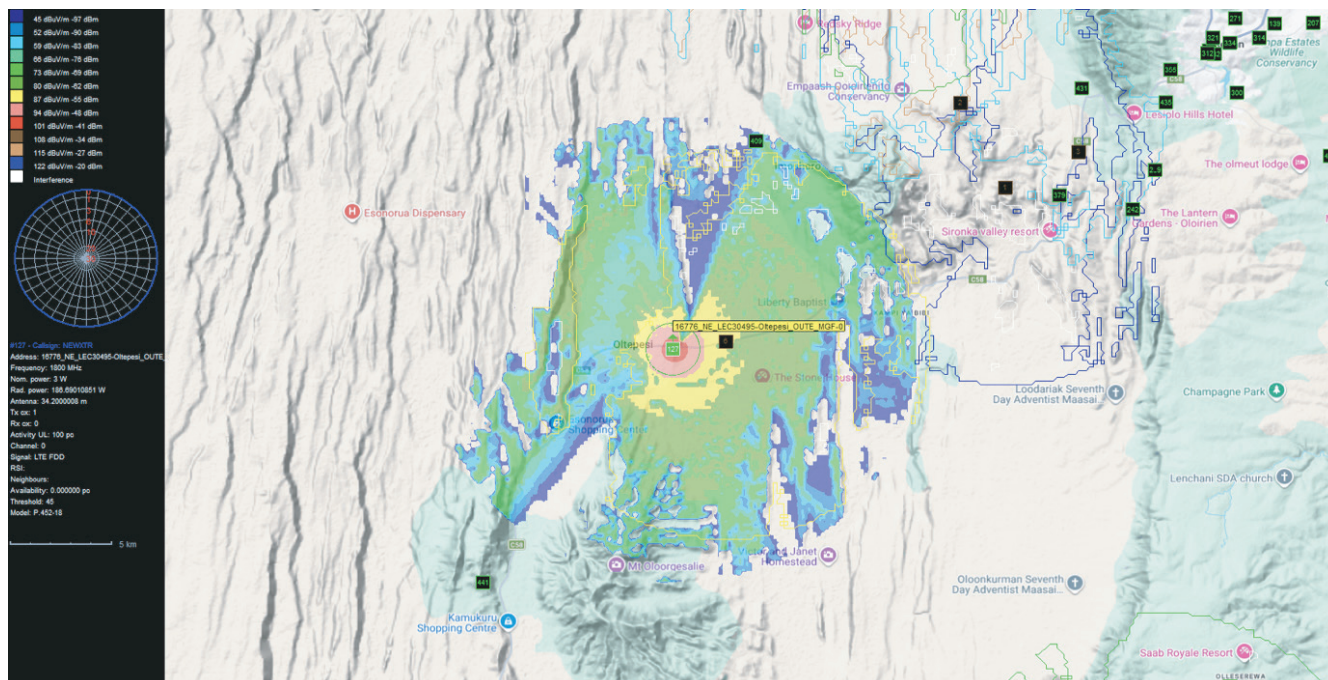


Figure 33: Zone C Oltepesi Tinga Safaricom Site 127 LTE Site Downlink Coverage Results

Due to the geographical characteristics of Oltepesi Tinga, the downlink signal coverage area is evenly distributed, with signals received from Safaricom LTE Site 127 in all directions. The signal strength gradually decreases from the centre towards the cell edges, reaching -89 dBm to -97 dBm. However, there are noticeable coverage gaps in the lower sections of the area, particularly towards the southwest.

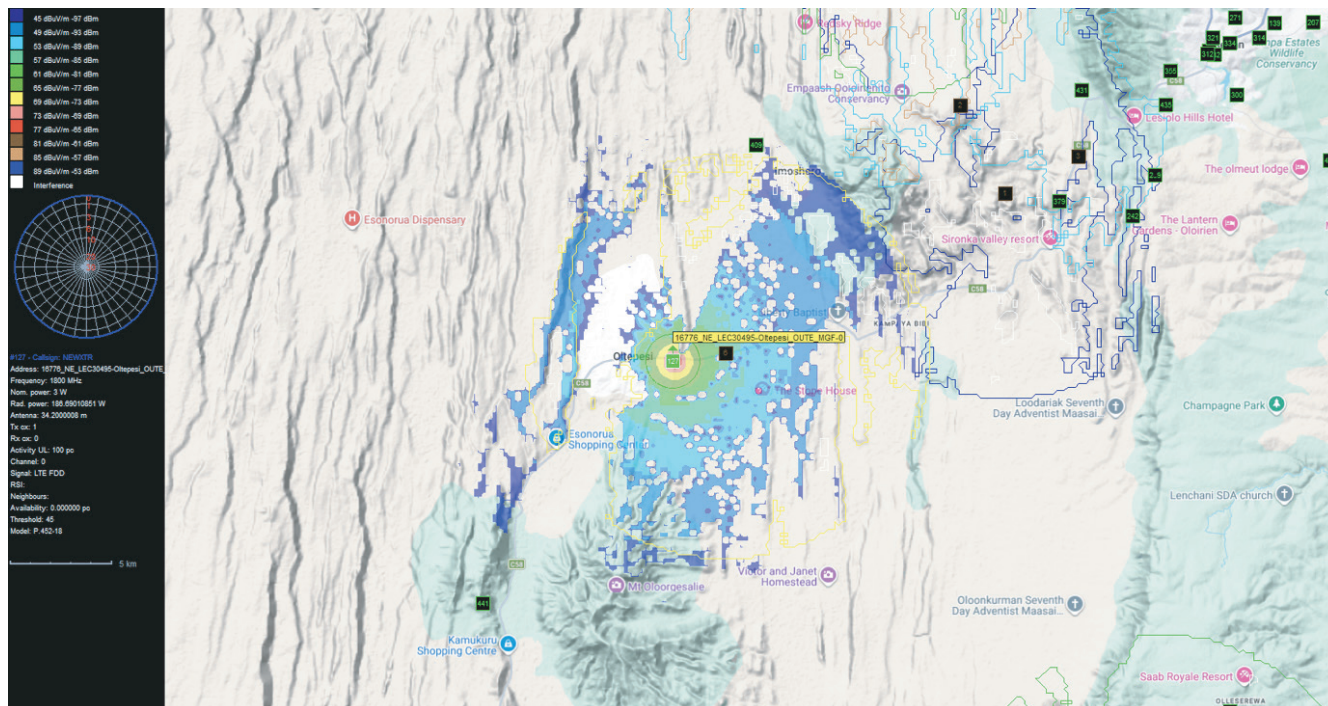


Figure 34: Zone C Oltepesi Tinga Safaricom Site 127 LTE Site Uplink Coverage Results

In contrast, the uplink signal coverage area in Oltepesi Tinga exhibits slightly different results. Lower regions in the southwestern direction, specifically towards the west and northwest, exhibit some coverage gaps. Signals at the western edge of the coverage map are received in the higher regions of Zone C, Oltepesi Tinga. Notably, significant gaps are also prominent in the western and northern regions. Generally, this coverage map indicates signal degradation in the uplink direction within the coverage area.

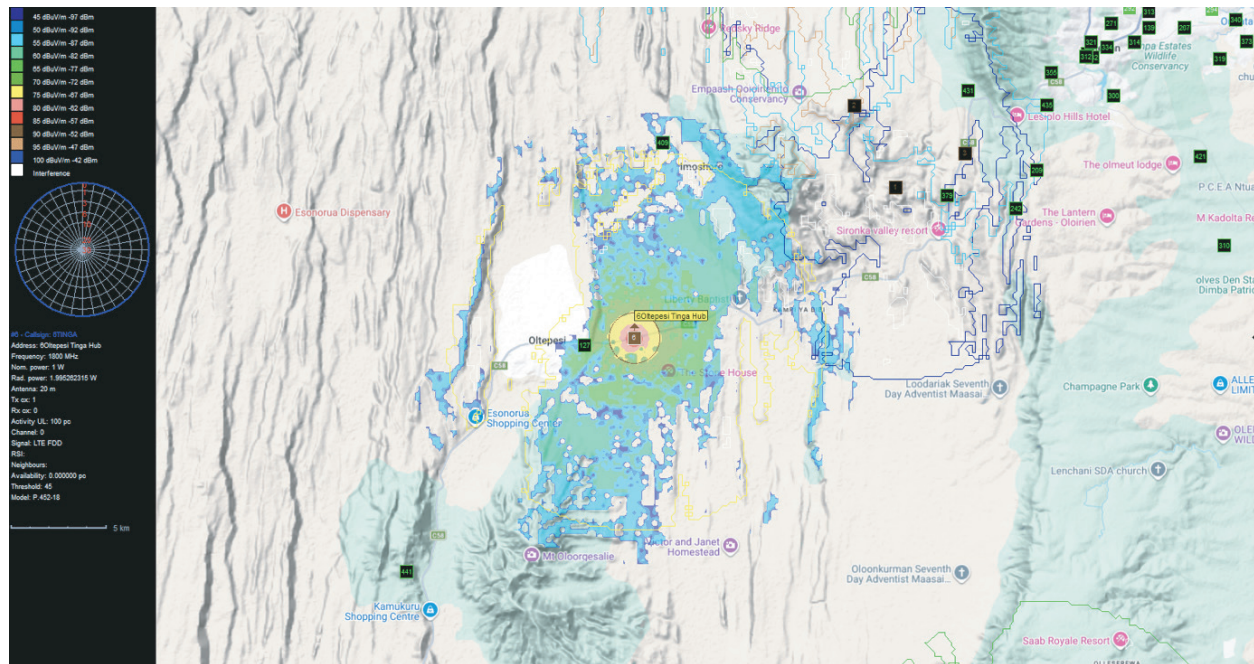
Table 6: Zone C Oltepesi Tinga NPN parameters

| " Site(s) Parameters                                                  | Tinga NPN Site LTE (FDD)                                                     |
|-----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Power                                                                 | 1W                                                                           |
| Frequency                                                             | 1800 MHZ                                                                     |
| TX Gain                                                               | 3.5dBi                                                                       |
| EIRP                                                                  | 1.995262W                                                                    |
| TX losses                                                             | 0.5dB                                                                        |
| Antenna Height                                                        | 20m                                                                          |
| TX/RX Bandwidth                                                       | 10MHZ                                                                        |
| Propagation Model                                                     | ITU-P542-18                                                                  |
| Technology                                                            | LTE FDD                                                                      |
| Sub Carrier Spacing                                                   | 15KHz                                                                        |
| Total RBs                                                             | 50                                                                           |
| Total Subcarriers                                                     | 600                                                                          |
| RB bandwidth                                                          | 180KHz                                                                       |
| Antenna Radiation                                                     | Isotropic                                                                    |
| Antenna Tilt                                                          | 0°                                                                           |
| Activity Uplink                                                       | 100%                                                                         |
| Activity Downlink                                                     | 100%                                                                         |
| TX Clutter /RX Clutter                                                | Provided in HTZ Software as DEM (Digital Elevation/Terrain Model) Maps       |
| RX Threshold dBu                                                      | 45 *conversion of (-97dBm) to field strength 45dBμV/m                        |
| Coverage Threshold dBu                                                | 68.3 * addition of RX threshold (45. BμV/m)and additional losses (23dB)      |
| RSRP (Reference Signal Received Power) Receiver Sensitivity threshold | -115 dBm                                                                     |
| KTBF (dBm) Thermal noise floor                                        | -97dBm                                                                       |
| C/I Requirement                                                       | -6.00 / -6.00                                                                |
| Height of RX antenna                                                  | 1.5m                                                                         |
| Cut off distance                                                      | 12km * Based on Communication Authority Max. Range in Rural areas guidelines |
| Minimum Coverage value dBu                                            | 30                                                                           |
| Wanted threshold                                                      | 45                                                                           |



## Zone C Oltepesi Tinga NPN Site Downlink AND UPLINK Coverage Results

Figure 35: Zone C Oltepesi Tinga NPN Site Downlink Coverage Results



The NPN at Tinga in Zone C, Oltepesi Tinga, provides extensive downlink coverage in all directions, extending more towards the north and south. However, the lower region to the west, near Oltepesi, is not fully covered. The signal then traverses the higher regions beyond the valley. A similar pattern is observed on the eastern side, albeit on a smaller scale.

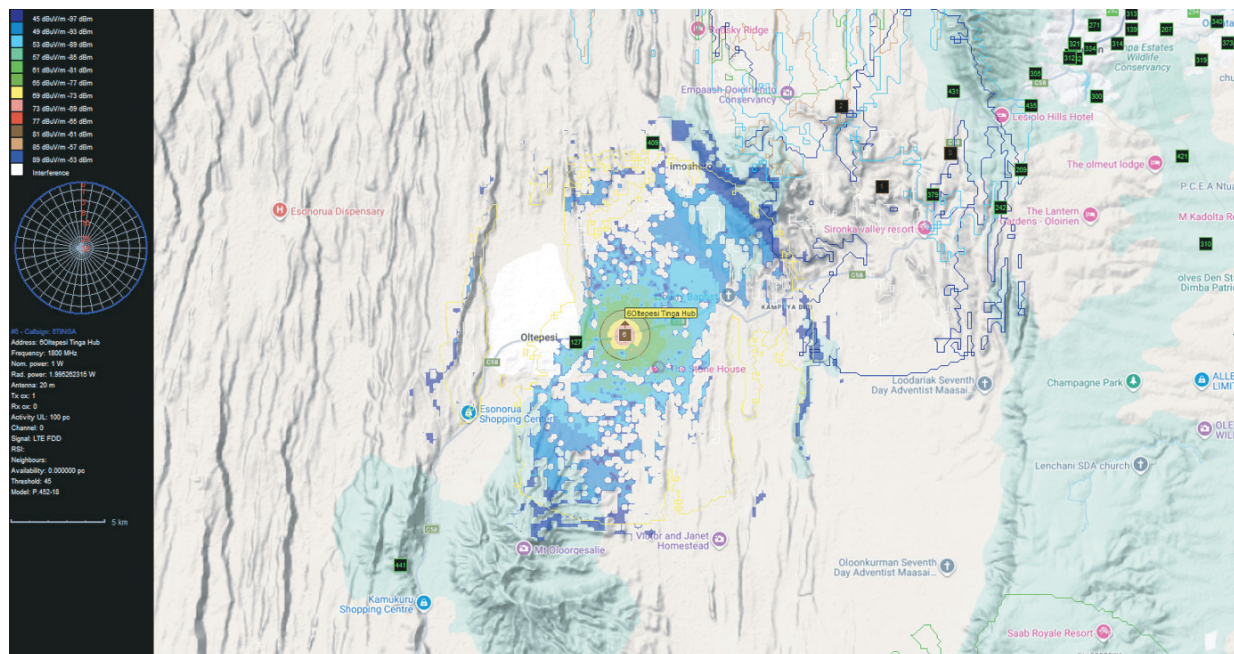


Figure 36: Zone C Oltepesi Tinga NPN Site Uplink Coverage Results



## Zone C Oltepesi Tinga Composite Coverage Downlink and Uplink Coverage Results



The composite coverage maps between Safaricom LTE Site 127 and the NPN site at Tinga exhibit a complementary coverage map that extends the coverage beyond the area that Safaricom LTE Site 127 in Figure 31 could reach in the downlink direction. The area southwest of Zone C Oltepesi Tinga experiences weak coverage, and the coverage area is reduced, but gaps still exist. In the uplink, the coverage area by both sites, Safaricom LTE Site 127 and the NPN site at Tinga, extends to cover a larger area. However, isolated coverage gaps are identified in the valley after Oltepesi and on the southwestern side of the coverage map for both Safaricom LTE Site 127 and the NPN site at Tinga.

## Zone C Oltepesi Tinga Best Server Coverage Results

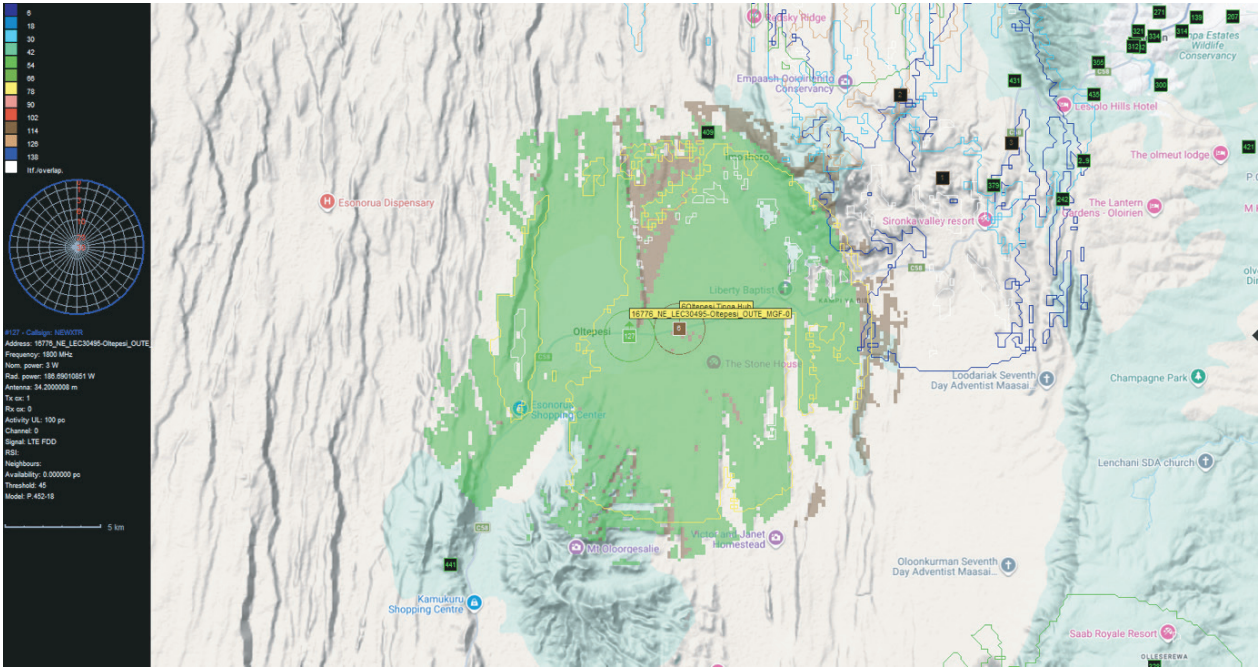


Figure 39: Zone C Oltepesi Tinga Best Server Coverage Results

Figure 39 illustrates the best server coverage results, demonstrating that Safaricom LTE Site 127 primarily serves Zone C Oltepesi Tinga. Notably, the NPN site at Tinga generates stronger signals that extend beyond the periphery, where Safaricom LTE Site 127 experiences reduced coverage. This can be attributed to the antenna height of Tinga’s NPN site, which stands at 20 meters. This elevation enables the site to effectively reach the lower elevations within the northeastern region of Zone C Oltepesi Tinga, which is overlooked by Safaricom LTE Site 127.



# Interference analysis

In the assessment of the 1800 MHz band, interference was modelled from two perspectives. The first perspective was co-channel interference between the NPN sites and the MNO sites, as the incumbents. This approach was adopted based on the assumption that all sites were deployed to operate in the 1800 MHz band. The second interference scenario was multi-channel or adjacent channel interference, where the incumbent MNOs were deployed in the 1800 MHz

band, and the NPN sites were allocated the 1825 MHz TX downlink frequency previously allocated to Telkom Kenya, although they (Telkom Kenya) do not have any active deployments in the area as of now. Furthermore, in both interference analysis scenarios and results, we still consider the four zones: Zone A - Kimuka Saikeri, Zone B-1 - Kisamis Corner, Zone B-2 - Kisamis Market, and Zone C - Oltepesi Tinga. We discuss this in the next subsections.

## Zone A – Kimuka Saikeri Co-Channel- Interference Map

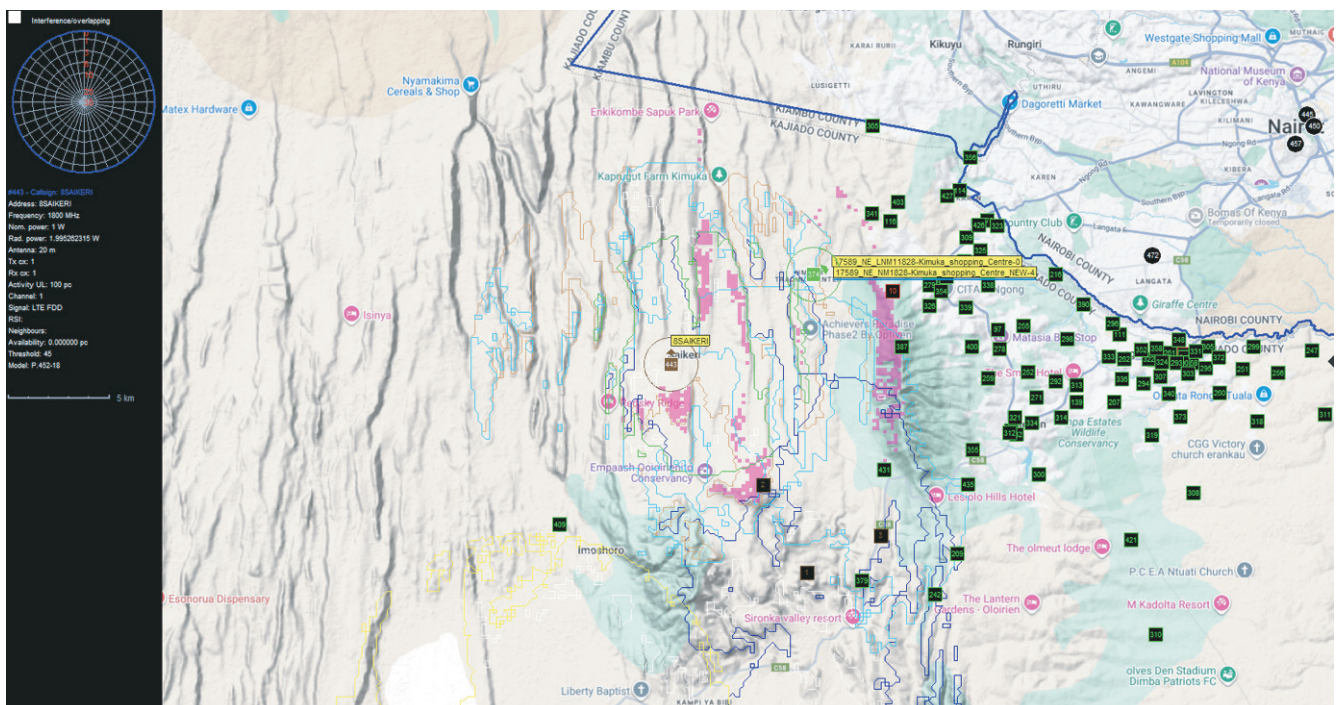


Figure 40: Zone-A-Kimuka-Safaricom and Saikeri NPN Co-Channel Interference

| Site Name          | Frequency | Percentage Interference | Verdict  |
|--------------------|-----------|-------------------------|----------|
| Safaricom Site 167 | 1800 MHZ  | 19.09%                  | Unusable |
| Saikeri NPN Site   | 1800 MHZ  | 22.28%                  | Unusable |

Table 7: Zone A – Kimuka Saikeri Co-Channel- Interference Report



The NPN site and Safaricom's Site 167 primarily interfere outwardly towards the Ngong hills region. We owe this to the distance between the two sites. Potential signal from the Saikeri NPN site overshoots and interferes with Safaricom's LTE Site 167. Similar interference is observed in the pink/magenta regions surrounding the NPN site at Saikeri. Saikeri reports a significant interference percentage of 22.28%, while Safaricom Site 167 reports 19.09%. In any case, co-channel interference is present in this zone, and the interference is likely to render the area unusable when both the NPN and Safaricom LTE Site 167 are active and reuse the 1800 MHz frequency band.

## Zone A – Kimuka Saikeri Multi-Channel- Interference Analysis

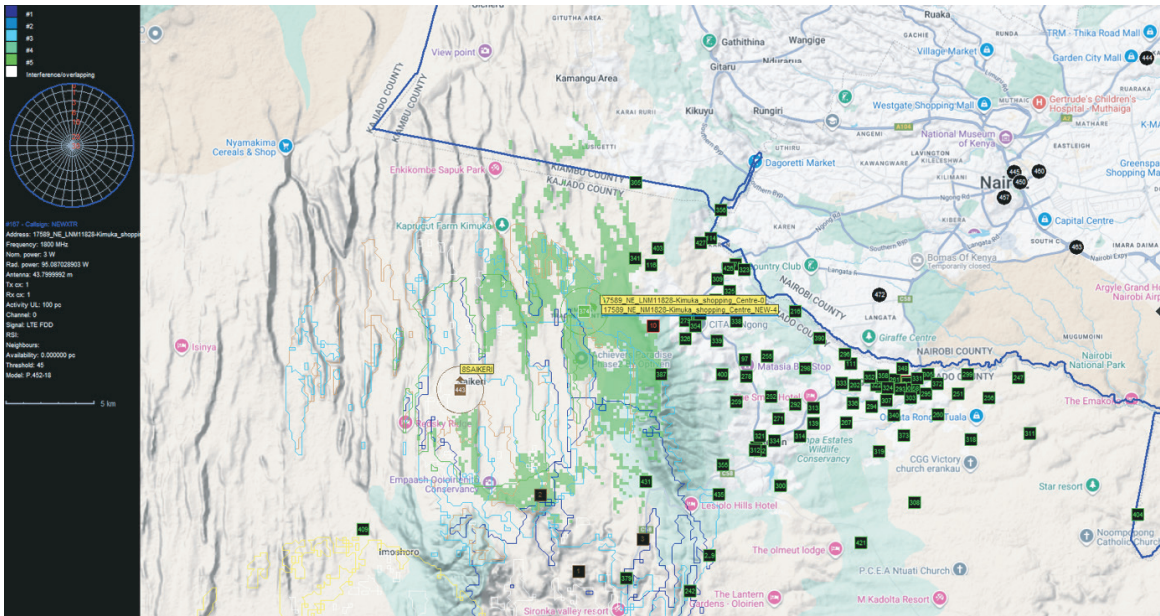


Figure 41: Zone-A-Kimuka-Safaricom and Saikeri NPN Multi-Channel Interference

| Site Name          | Frequency | Percentage Interference | Verdict |
|--------------------|-----------|-------------------------|---------|
| Safaricom Site 167 | 1800 MHZ  | 00.00%                  | Usable  |
| Saikeri NPN Site   | 1800 MHZ  | 00.00%                  | Usable  |

In the adjacent channel interference analysis report for Zone A - Kimuka Saikeri, presented in Figure 41 and Table 15, the interference is substantially reduced. Both sites report no interference, and the Zone becomes functional when both the NPN and Safaricom LTE Site 167 are operational and operate on adjacent channels of 1800 MHz and 1825 MHz frequency bands, as indicated in Table 15.

## Zone B-1- Kisamis Corner Co-Channel- Interference Map: Safaricom vs 3NPNs

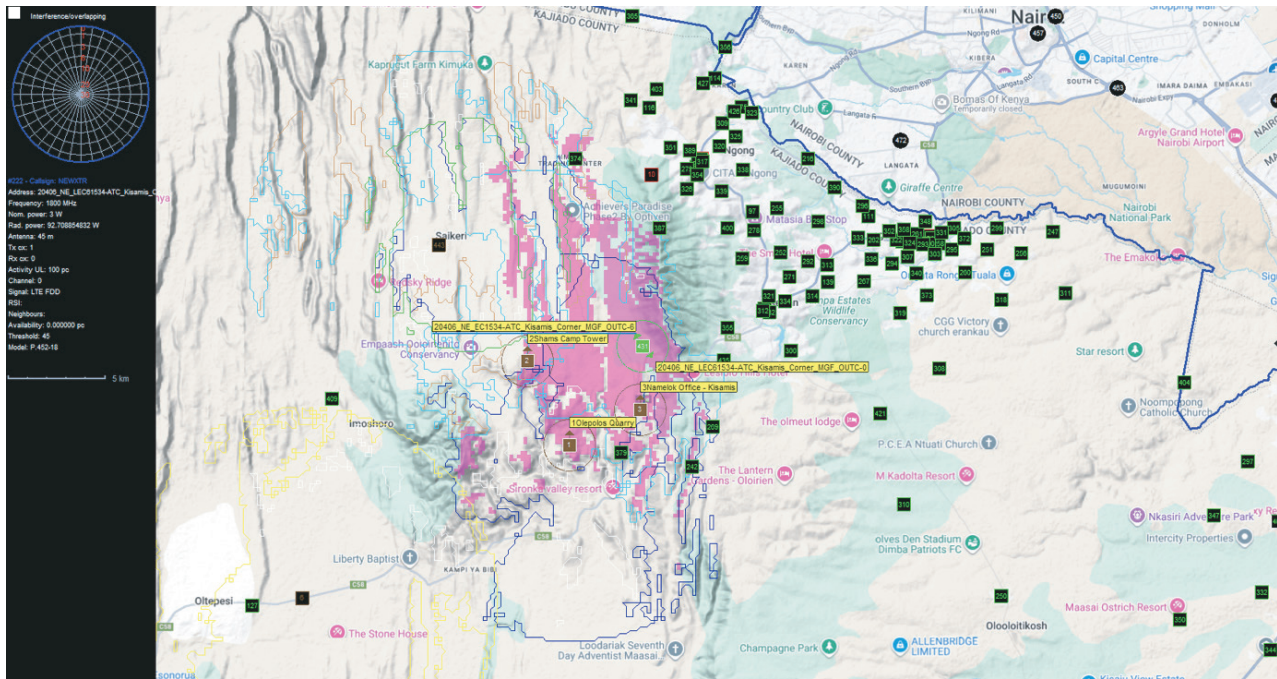


Figure 42: Zone B-1- Kisamis Safaricom vs 3NPNs Co-Channel- Interference

| Site Name                       | Frequency | Percentage Interference | Verdict  |
|---------------------------------|-----------|-------------------------|----------|
| Safaricom Site 222              | 1800 MHZ  | 75.99%                  | Unusable |
| Olepolos Quarry NPN Site        | 1800 MHZ  | 75.26%                  | Unusable |
| Shams Camp NPN site             | 1800 MHZ  | 61.82%                  | Unusable |
| Namelok Office Kisamis NPN Site | 1800 MHZ  | 88.15%                  | Unusable |

Table 9: Zone B-1- Kisamis Corner Co-Channel- Interference Report Safaricom Vs 3 NPNs

Significant interference is present in Zone B-1, Kisamis Corner. As depicted in Figure 42, Olepolos Quarry NPN Site and Namelok Office Kisamis NPN Site are the closest to Safaricom LTE Site 222, while Shams Camp NPN Site is slightly further away. As shown in Figure 42, co-channel interference is significantly high when Olepolos Quarry NPN Site and Namelok Office Kisamis NPN Site are close to Safaricom LTE Site 222. This interference primarily spreads northward from Sham's Camp NPN Site.

From the report in Table 16, we observe that Safaricom Site 222, Olepolos Quarry NPN Site, and Namelok Office Kisamis NPN Site experienced the highest interference percentages, ranging from 75.99%, 75.26%, and 88.15%, respectively. Sham's Camp NPN Site had a relatively lower interference percentage of 61.82%. Nevertheless, these values are significantly high and pose a significant challenge to coexistence in this zone. Co-channel interference in this area will render the area unusable when the three NPN sites and Safaricom LTE Site 222 are active and reuse the 1800 MHz frequency band.



## Zone B-1- Kisamis Corner Multi-Channel- Interference Map

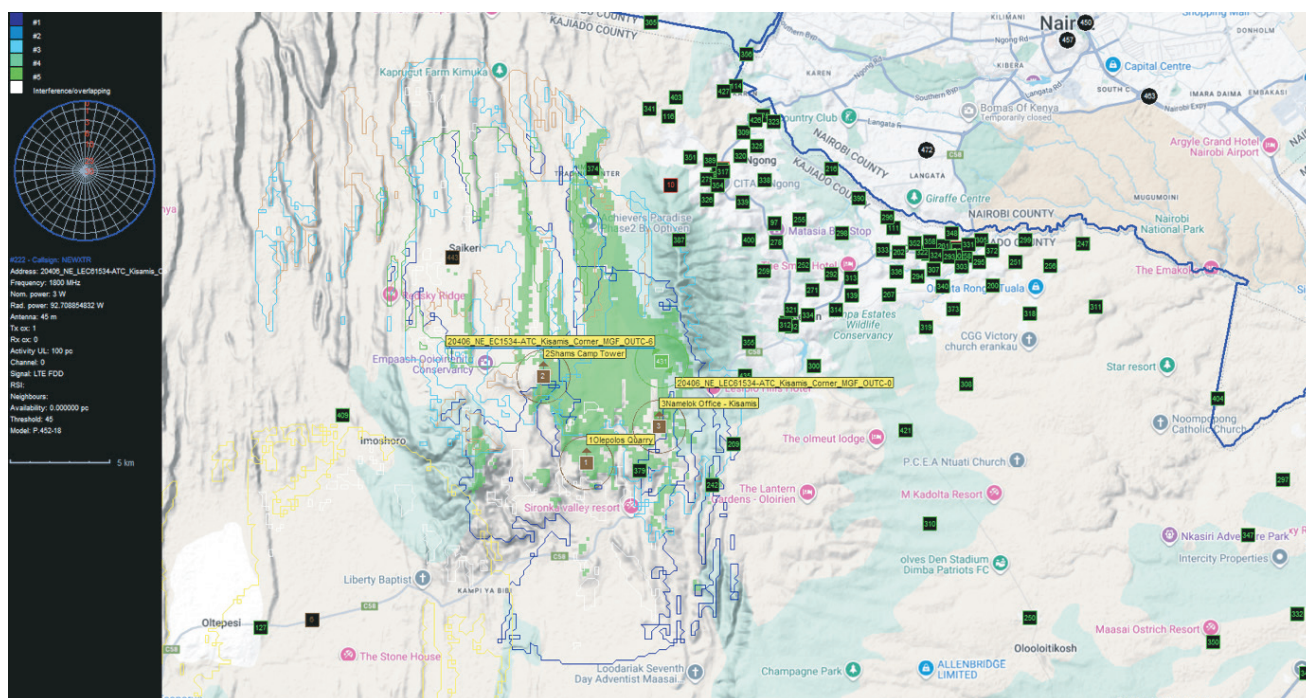


Figure 43: Zone B-1- Kisamis Safaricom vs 3NPNs Multi-Channel- Interference

| Site Name                       | Frequency | Percentage Interference | Verdict |
|---------------------------------|-----------|-------------------------|---------|
| Safaricom Site 222              | 1800 MHZ  | 0.00%                   | Usable  |
| Olepolos Quarry NPN Site        | 1800 MHZ  | 0.00%                   | Usable  |
| Shams Camp NPN site             | 1800 MHZ  | 0.00%                   | Usable  |
| Namelok Office Kisamis NPN Site | 1800 MHZ  | 0.00%                   | Usable  |

Table 10: Zone B-1- Kisamis Corner Multi-Channel- Interference Report

Interference percentage results improve in Zone B-1 Kisamis Corner when the three NPN sites operate on adjacent frequency bands at 1825 MHz, while Safaricom Site 222 retains the 1800 MHz band. We observe no co-channel interference between the NPN sites since they transmit at 1W, resulting in a small coverage area. Consequently, Zone B-1 Kisamis Corner becomes functional when all the NPNs and Safaricom LTE Site 222 are operational and operate on adjacent channels of 1800 MHz and 1825 MHz frequency bands, as indicated in Table 17.



## Zone B-2- Kisamis Market Co-Channel- Interference Map: Safaricom vs 3NPNs

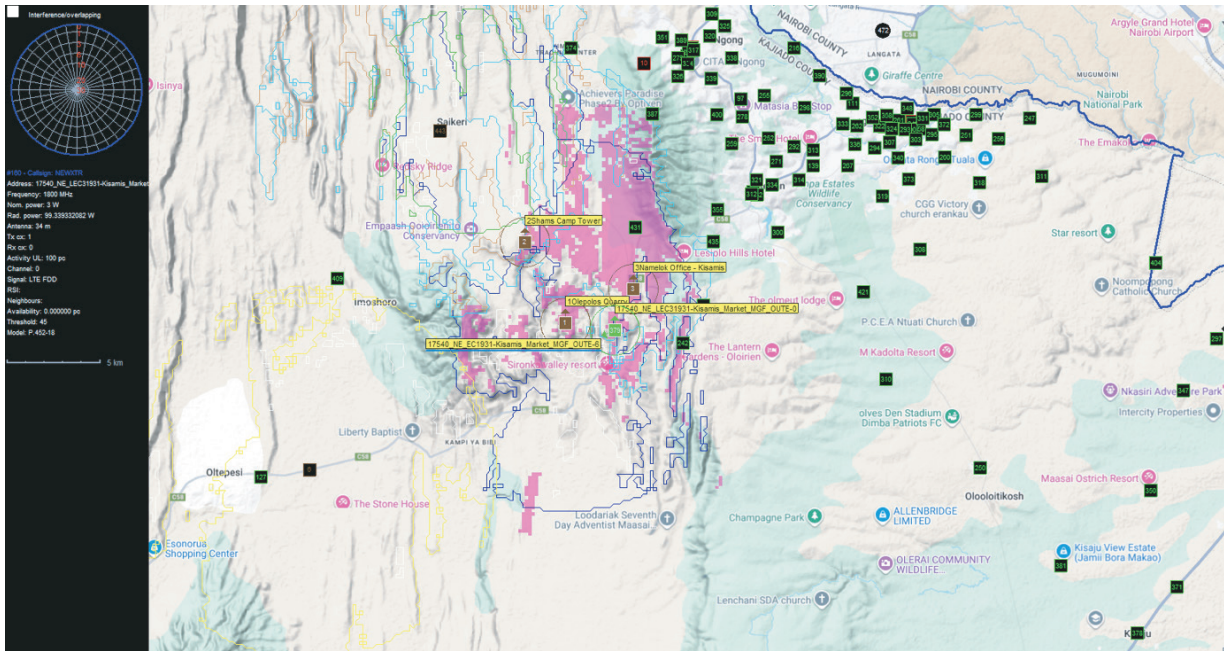


Figure 44: Zone B-2- Kisamis Market Safaricom vs 3NPNs Co-Channel- Interference

| Site Name                       | Frequency | Percentage Interference | Verdict |
|---------------------------------|-----------|-------------------------|---------|
| Safaricom Site 160              | 1800 MHZ  | 46%                     | Usable  |
| Olepolos Quarry NPN Site        | 1800 MHZ  | 83.04%                  | Usable  |
| Shams Camp NPN site             | 1800 MHZ  | 46.33%                  | Usable  |
| Namelok Office Kisamis NPN Site | 1800 MHZ  | 80.16%                  | Usable  |

Table 11: Zone B-2- Kisamis Market Co-Channel- Interference Report: Safaricom Vs 3 NPNs

The interference report in Zone B-2, Kisamis Market as shown in Table 18 and Figure 44, indicates a similar co-channel interference phenomenon to the report observed in Zone B-1, Kisamis Corner in Table 16. The three NPN sites interfere significantly with Safaricom Site 160.

In this instance, Olepolos Quarry NPN site and Namelok Office Kisamis NPN site are the closest to Safaricom LTE Site 160, while Shams Camp NPN site is slightly further away. The interference report reflects this, with interference percentages of 46% at Safaricom Site 160, 83.04% at the Olepolos Quarry NPN site, 46.33% at Shams Camp NPN site, and 80.16% at Namelok Office Kisamis NPN Site. The figures decrease to relatively lower levels from Shams Camp NPN site because Safaricom Site 160 is further away from Sham's camp compared to the distance between Zone B-1, Kisamis Corner, and Zone B-2, Kisamis Market.

Zone B-2- Kisamis Market Multi-Channel- Interference Map: Safaricom vs 3NPNs

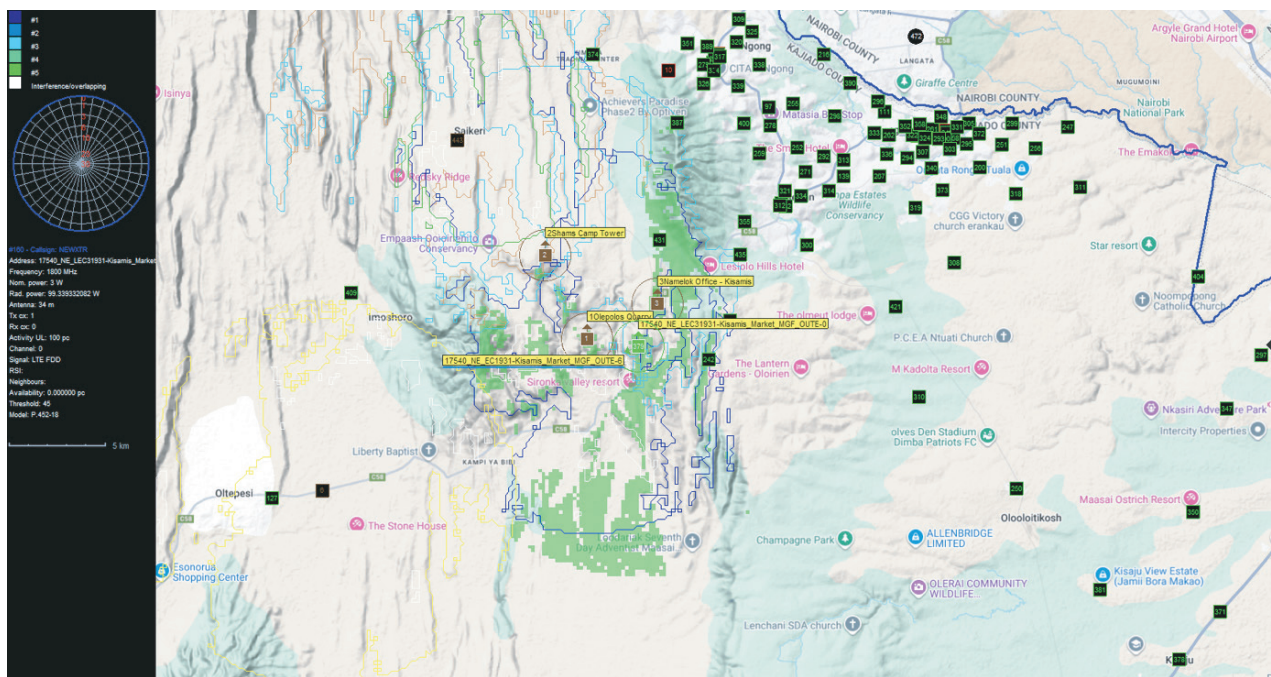


Figure 45: Zone B-2- Kisamis Market Safaricom vs 3NPNs Multi-Channel- Interference

| Site Name                       | Frequency | Percentage Interference | Verdict |
|---------------------------------|-----------|-------------------------|---------|
| Safaricom Site 160              | 1800 MHZ  | 0.00%                   | Usable  |
| Olepolos Quarry NPN Site        | 1825 MHZ  | 0.00%                   | Usable  |
| Shams Camp NPN site             | 1825 MHZ  | 0.00%                   | Usable  |
| Namelok Office Kisamis NPN Site | 1825 MHZ  | 0.00%                   | Usable  |

Table 12: Zone B-2- Kisamis Market Multi-Channel- Interference Report: Safaricom Vs 3 NPNs

Similar to the results obtained from Zone B-1 Kisamis Corner regarding multi-channel/adjacent channel interference, the percentage results in Zone B-2 Kisamis Market are improved when the three NPN sites operate on adjacent frequency bands at 1825 MHz, while Safaricom Site 160 retains the 1800 MHz band. Notably, there is no co-channel interference between the NPN sites due to their low-power transmission of 1W, resulting in a limited coverage area. Consequently, Zone B-1 Kisamis Corner becomes functional when all the NPN sites and Safaricom LTE Site 160 are operational and operate on adjacent channels of 1800 MHz and 1825 MHz frequency bands, as specified in Table 19.

# Zone C Oltepesi Tinga Co-Channel- Interference Map

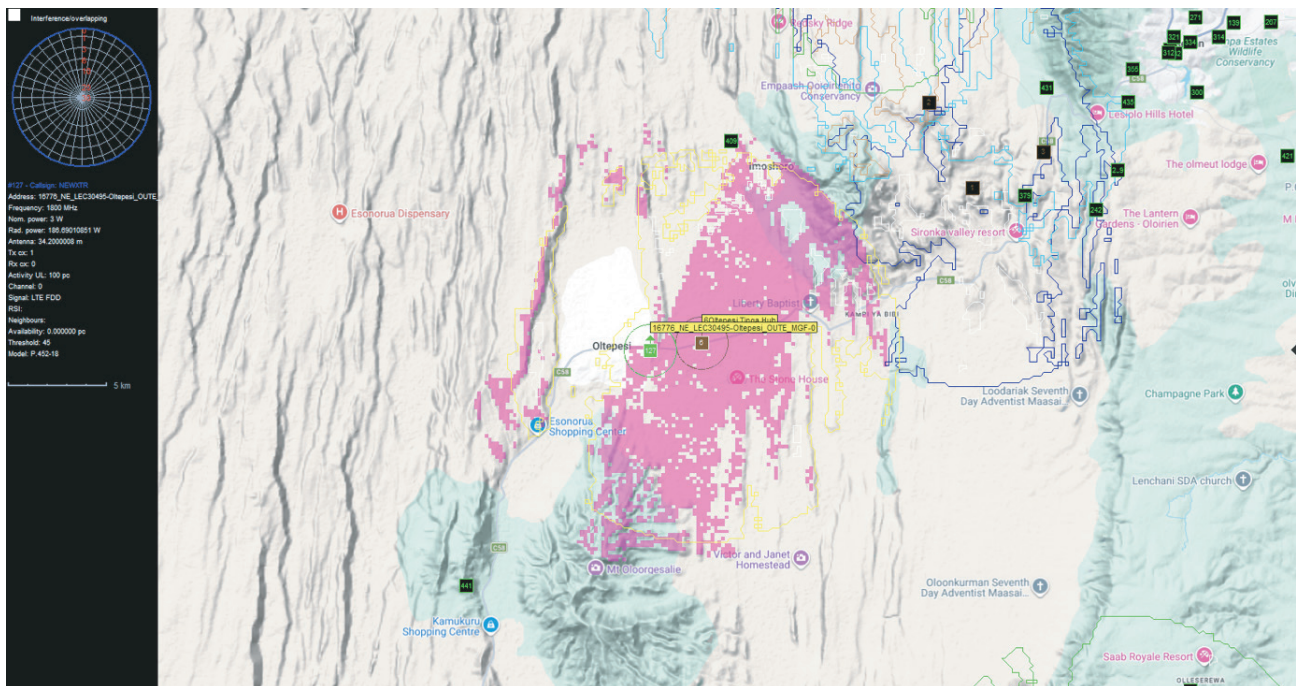


Figure 46: Zone C Oltepesi Tinga Safaricom vs NPNs Co-Channel- Interference

| Site Name               | Frequency | Percentage Interference | Verdict |
|-------------------------|-----------|-------------------------|---------|
| Safaricom Site 127      | 1800 MHZ  | 78.15%                  | Usable  |
| Oltepesi Tinga NPN Site | 1800 MHZ  | 72.54%                  | Usable  |

Table 13: Zone C Oltepesi Tinga Co-Channel- Interference Report

Co-channel interference in Zone C, Oltepesi Tinga is significant and evident due to the proximity of the sites, Safaricom Site 127 and Oltepesi Tinga NPN Site as shown in Figure 46. The interference map closely aligns with the coverage area depicted in the composite uplink coverage map earlier in Figure 36, indicating substantial interference between the two sites. Specifically, Safaricom Site 127 reports an interference percentage of 78.15%, while Oltepesi Tinga NPN Site reports 72.54%. Consequently, co-channel interference is present in this Zone C Oltepesi Tinga, potentially rendering the area unusable for operation when both the Oltepesi Tinga NPN Site and Safaricom LTE Site 127 are active and concurrently utilise the 1800 MHz frequency band.



## Zone C Oltepesi Tinga Multi-Channel- Interference Map

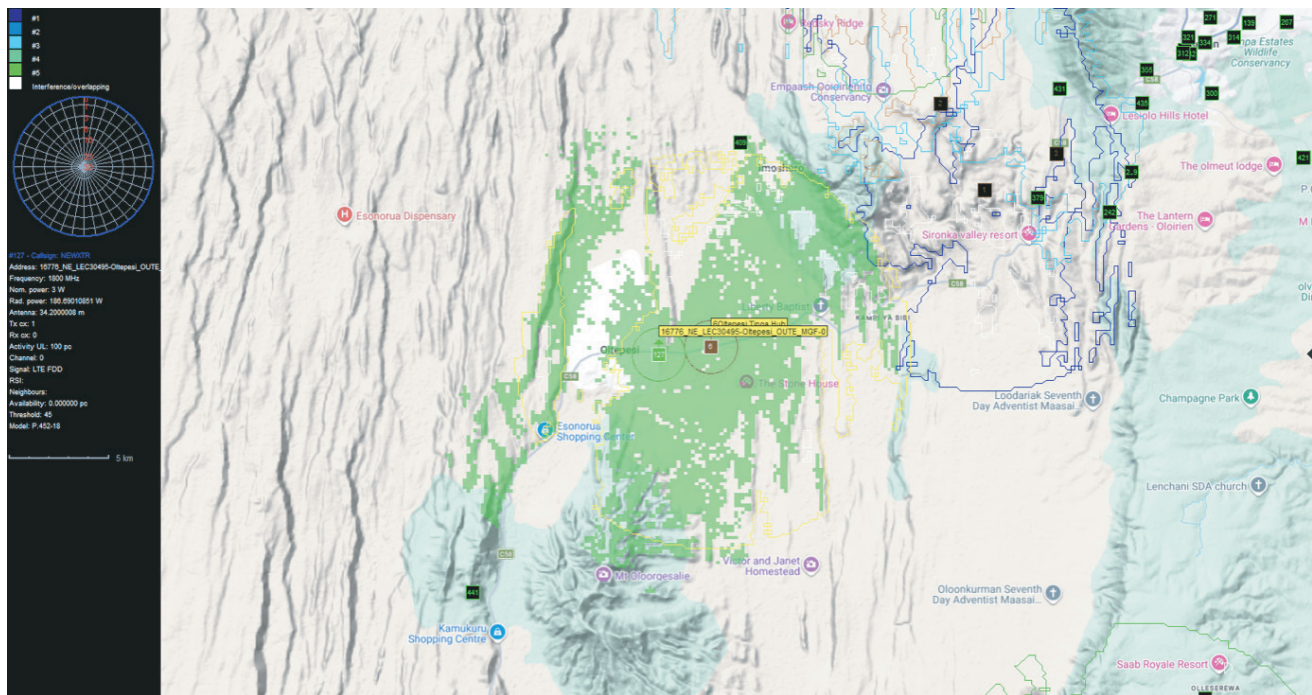


Figure 47: Zone C- Oltepesi Tinga Safaricom vs NPNs Co-Channel- Interference

| Site Name               | Frequency | Percentage Interference | Verdict |
|-------------------------|-----------|-------------------------|---------|
| Safaricom Site 127      | 1800 MHZ  | 00.00%                  | Usable  |
| Oltepesi Tinga NPN Site | 1800 MHZ  | 00.00%                  | Usable  |

Table 14: Zone C Oltepesi Tinga Multi-Channel- Interference Report

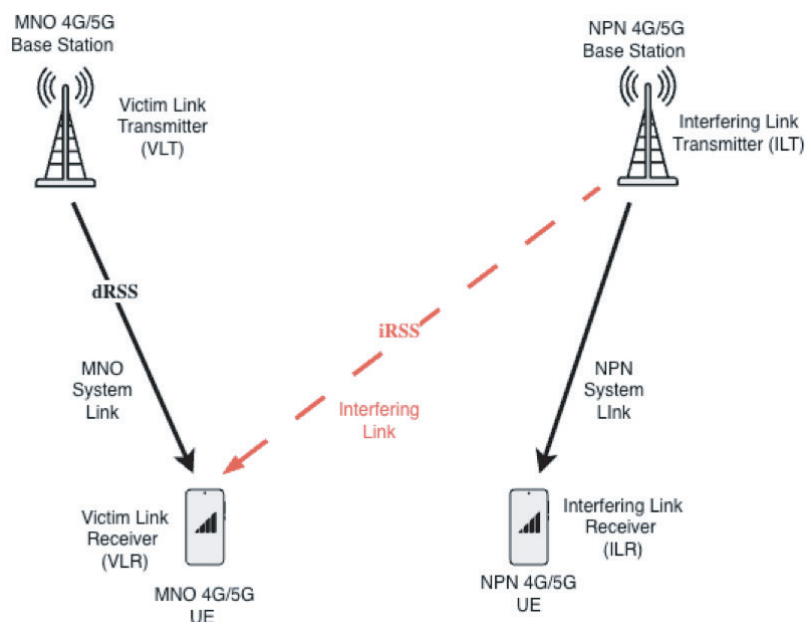
Zone C Oltepesi Tinga demonstrates improved or no interference when Safaricom Site 127 and Oltepesi Tinga NPN Site utilise adjacent channels. Both sites report no interference. The Zone C Oltepesi Tinga becomes functional when both the Oltepesi Tinga NPN Site and Safaricom LTE Site 127 are operational and operate on adjacent channels of 1800 MHz and 1825 MHz frequency bands, as specified in Table 20.

## Coexistence studies: Unmitigated Co-existence Baselines vs Interference Mitigation and Coexistence Optimisation Strategies

This coexistence study report examines the coexistence of different zones, as discussed earlier: Zone A (Kimuka Saikeri), Zone B-1 (Kisamis Corner), Zone B-2 (Kisamis Market), and Zone C (Oltepesi Tinga). The coexistence studies approach employed by this report initially analyses the unmitigated coexistence baseline in all the four zones. This baseline study involves obtaining site placement and inter-site distance values from the fieldwork study results and augmenting them with CA data obtained from the HTZ ATDI tool. This approach provides precise site-placement information and the transmission-path azimuth between the victim MNO sites and the NPN sites serving as interferers. Subsequently, the study employs two interference mitigation and coexistence optimisation strategies: an inter-site distance of 15 km between the NPN site and the victim MNO site and multi-channel transmission between the NPN and Victim Link Transmitter (VLT) MNO sites. In this multi-channel transmission, we also analyse Adjacent Channel Interference (ACI) scenarios. Throughout these approaches, the report presents the following results:

1. *The average desired Received Signal Strength (dRSS) of the reference cell.*
2. *The average non-interfered bit rate.*
3. *Non-interfered SNIR for all sites.*
4. *Interfering Received Signal Strength (iRSS), which is the average unwanted external interference.*
5. *The average interfered bit rate.*
6. *Interfered SNIR for all sites.*

At the base of this coexistence study, the MNO systems are considered as the victims while the potential NPNs are considered the interferers. In this regard, downlink transmissions from the MNO to the 4G or 5G UE in the MNO system link provides the desired Received Signal Strength (dRSS) while the modelled NPN base stations produce the interfering signal depicted as interfering Received Signal Strength (iRSS). A generalised interaction between the Victim system and the interfering system is shown in Figure 48. This approach is cascaded and modified to suit the Zones with different victims and interfering scenarios.



## Preliminaries

To model coexistence in both scenarios discussed above, as well as the two-interference mitigation and co-existence optimisation strategies, the following preliminary considerations, assumptions and constants were considered.

1. The propagation model for all sites is ITU-P542-18.
2. The NPN sites' cell radius is 2.5 km. This is informed by coverage analysis of the NPN sites in the uplink direction for meaningful connectivity and guidance from previous implementations such as
3. The maximum coverage area for Victim MNO sites is 10 km. The cell layout is a single-cell omnidirectional site with a cell radius of 10 km. This is informed by analysis of coverage results, where on average, -73 dB could be achieved at a 10 km radius downlink.
4. The maximum allowable degradation to the LTE cell's performance by the OFDMA downlink/uplink system, as determined by the Average Bitrate Loss of 5% derived from ECC Reports 283 and 326.
5. The minimum coupling loss for all the receivers was 70dB. Guided by 3GPP ranges of Minimum Coupling Loss between BS and UE.
6. The inter-site distance is obtained from the HTZ ATDI tool, represented as the relative distance to the VLT from the ILT.
7. The radiated power for Safaricom sites was a constant 3 W.
8. The antenna heights for the NPN sites are based on existing CN network sites run by Namelok CN. The NPN antennas will be collocated here.
9. NPN antennas have a tilt of 0 to maximise the NPN coverage area. This is juxtaposed with Safaricom's site antenna tilts to model expected interference.
10. We use this formula to convert the HTZ bearing angle to SEAMCAT geometric angles.

*Equation 1: Converting HTZ bearing angle to SEAMCAT geometric angles*

$$\theta_{SC} = (90^\circ - \alpha_{HTZ}) \pmod{360^\circ}$$

*These coexistence studies simulations were modelled on SEAMCAT with 20,000 events for each simulation.*



## Zone a Kimuka Saikeri Co-existence Study

| Parameters                            | Safaricom LTE Site Zone A (VLT) | Saikeri Zone A NPN Site (ILT) |
|---------------------------------------|---------------------------------|-------------------------------|
| Power                                 | 3W                              | 1W                            |
| Frequency                             | 1800 MHZ                        | 1800 MHZ                      |
| TX Gain                               | 15.51dBi                        | 3.5dBi                        |
| EIRP                                  | 95.08703W                       | 2.238721W                     |
| losses                                | 0.5db                           | 0                             |
| Antenna Height                        | 43.8m                           | 20m                           |
| Cell Radius                           | 10km                            | 2.5km                         |
| TX/RX Bandwidth                       | 10MHZ                           | 10MHZ                         |
| Propagation Model                     | ITU-R-P542-18                   | ITU-R-P452-18                 |
| Technology                            | LTE FDD                         | LTE FDD                       |
| Sub Carrier Spacing                   | 15KHz                           | 15KHz                         |
| Total RBs                             | 50                              | 50                            |
| Total Subcarriers                     | 600                             | 600                           |
| RB bandwidth                          | 180KHz                          | 180KHz                        |
| RX noise figure                       | 7 dB                            | 7 dB                          |
| Minimum Coupling loss                 | 70 dB                           | 70 dB                         |
| Handover Margin                       | 1.5 dB                          | 1.5 dB                        |
| Standard Desensitization              | 6 dB                            | 6 dB                          |
| Target I/N                            | -6 dB                           | -6 dB                         |
| Antenna Radiation                     | Isotropic                       | Isotropic                     |
| Antenna Pattern TX                    | ITU-R F.1336                    | ITU-R F.1336                  |
| Antenna Arrays TX/RX                  | 1/1                             | 1/1                           |
| Antenna Tilt                          | 60 degrees                      | 0                             |
| Activity Uplink                       | 100%                            | 100%                          |
| Activity Downlink                     | 100%                            | 100%                          |
| TX Clutter                            | Open-Rural                      | Open-Rural                    |
| RX Clutter                            | Open-Rural                      | Open-Rural                    |
| Relative Distance to VTL              | NA                              | 8.2455                        |
| Path Azimuth Relative to ILT from VLT | NA                              | 213.7                         |

Table 15: Zone A Kimuka Saikeri Co-existence Parameters

## Zone A – Kimuka Saikeri: Unmitigated Co-existence Baseline

In Zone-A, Kimuka Saikeri Safaricom LTE Site 374 is the victim, while Saikeri NPN Site is the interferer. The network layout shown in Figure 48 represents this scenario, based on the coexistence parameters outlined in the preceding Table 22.

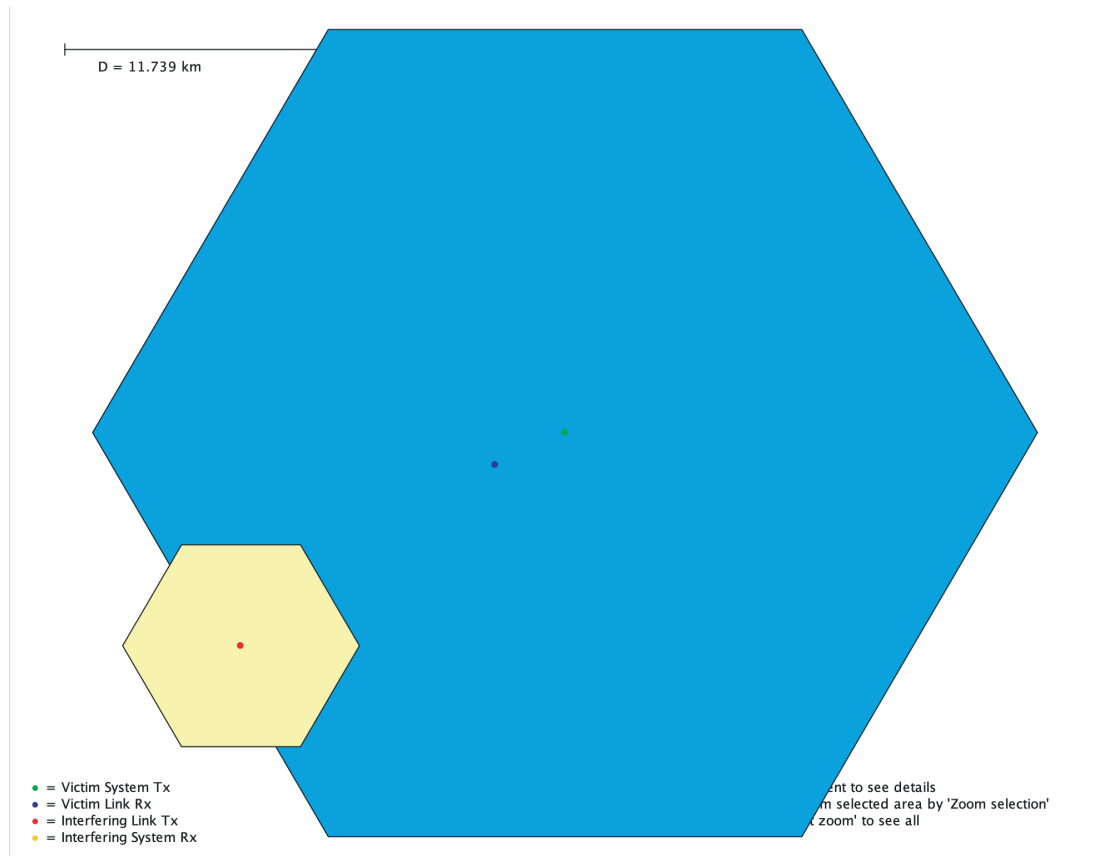


Figure 49: Zone A Kimuka Saikeri Unmitigated Coexistence Scenario Network Layout

| Victim Results                | ILT Link Results      |
|-------------------------------|-----------------------|
| Average bitrate loss : 24.51% | Sub-carrier ratio 0.2 |
| Sub-carrier ratio 1.0         |                       |

Table 16: Zone A – Kimuka Saikeri: Unmitigated Co-Existence Baseline Results

The average bitrate loss in this scenario is 24.51%, which exceeds the desired maximum allowable degradation of 5% for Average Bitrate Loss in the LTE system. This indicates that the two systems are incompatible and cannot guarantee seamless coexistence in the reference cluster.

The average dRSS was -86.16 dBm, with maximum values of -49.9 dBm and minimum values of -98.27 dBm at the cell edge as the worst-case scenario. Less than 5% of the simulated values were below the receiver's noise floor of -96.77 dBm. This indicates that the modelled victim cell has adequate reception without interference from the NPN site.

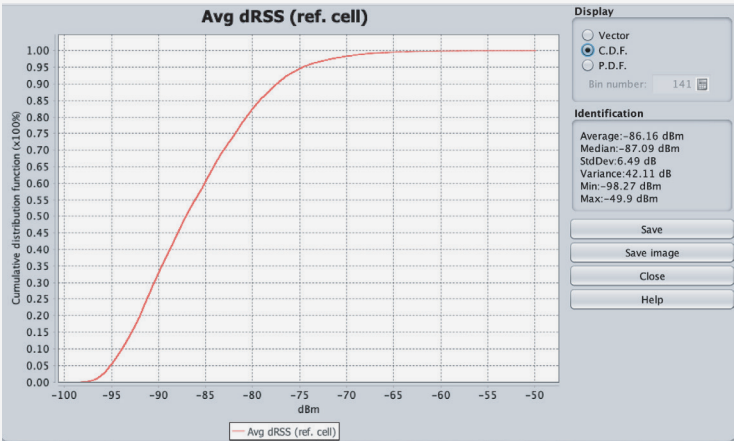


Figure 50: Zone A Kimuka Saikeri  
Unmitigated Coexistence Scenario Average dRSS of the reference cell

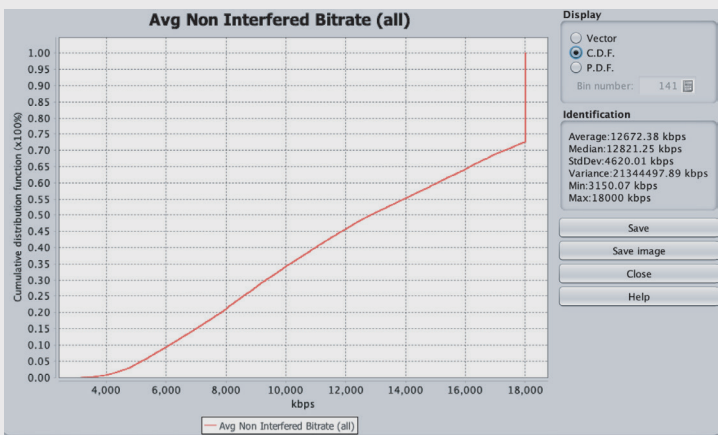


Figure 51: Zone A Kimuka Saikeri  
Unmitigated Coexistence Scenario Average Non Interfered Bitrate

The Safaricom Victim system in Zone A Kimuka Saikeri achieved an average bitrate of 12.6 Mbps as seen in Figure 49. The minimum bitrate in the worst-case scenarios for this run was 3.15 Mbps. We observe that approximately 27% of the simultaneous events attain the maximum bitrate of 18 Mbps.

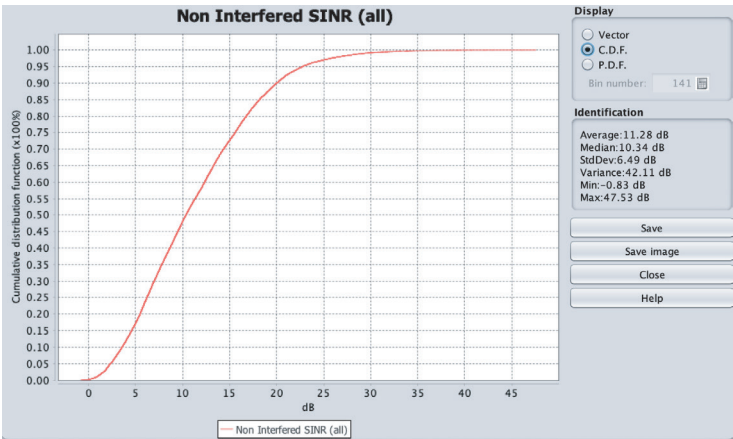


Figure 52: Zone A Kimuka Saikeri  
Unmitigated Coexistence Scenario Non-Interfered SINR

The link quality of the non-interfered victim system exhibits an average of 11.28 dB and a median SINR of 10.34 dB. At the extreme edge, the minimum SINR recorded is -0.83 dB, while the maximum recorded SINR is 47.53 dB. Figure 50 shows unmitigated non-interfered SINR results.



## Zone A – Kimuka Saikeri: Unmitigated Co-Existence Interference

This interfering Received Signal Strength (iRSS) is signal leakage into the victim's receiver. The average Unwanted Interference (iRSS) is -99.19 dBm, which is still weaker than the desired average dRSS (-86.16 dBm). The median Unwanted Interference (iRSS) is -101.10 dBm, which is still weaker than the desired median dRSS (-87.09 dBm). The worst-case scenario is from -98.27 dBm in the non-interfering case to -117.46 dBm. In the interfering scenario, the ILT's leaks into the victim's receiver with a signal strength of -34.12 dBm, which is slightly higher than the victim's maximum values of -49.9 dBm. This indicates interference from the ILT causing performance degradation which is responsible for the average bitrate loss of 24.51% presented in Table 22.

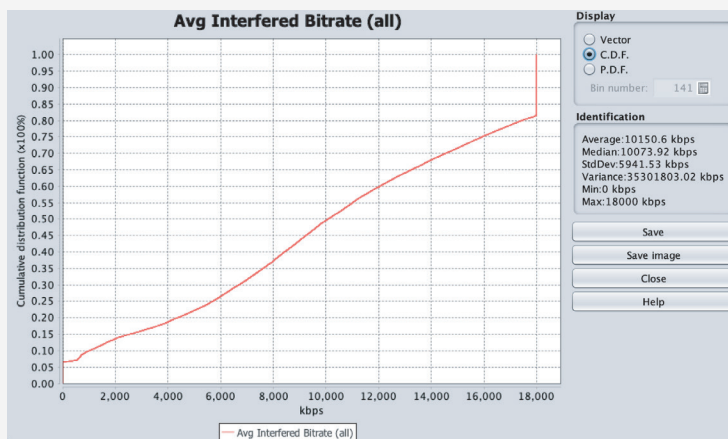


Figure 54: Zone A – Kimuka Saikeri:

Unmitigated Co-Existence Average Interfered Bitrate

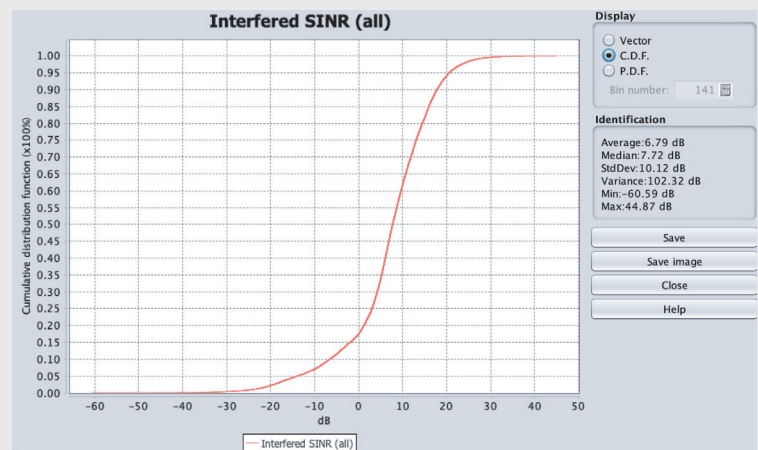


Figure 55: Zone A – Kimuka Saikeri:

Unmitigated Co-Existence Interfered SINR

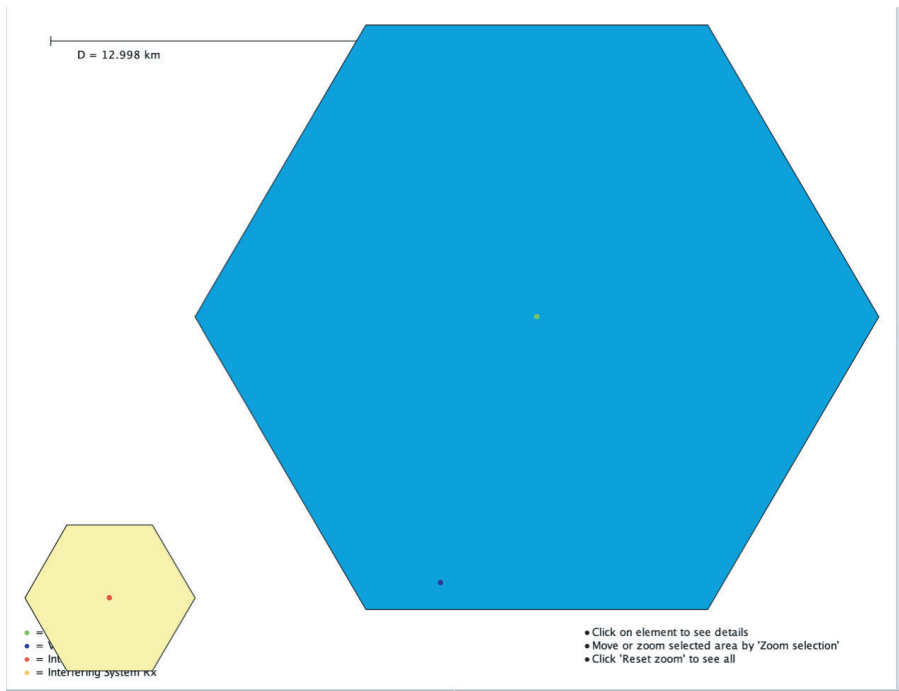
When the system is interfered with by the interfering link from the NPN at Saikeri, the average bitrate drops to 10.1 Mbps with a higher standard deviation as seen in Figure 52. On the other hand, the worst-case scenario reports a bitrate of 0 kbps. This means that in the worst case, the receiver and transmitter could exchange no data despite being connected due to interference from the ILT. Additionally, with interference from the ILT, less than 19% of the scenarios could attain the maximum bitrate during the transmission of 18 Mbps.

Conversely, in comparison to the non-interfered SINR, the link quality of the interfered victim system deteriorates. Form Figure 53, the average SINR drops from 11.28 dB to 6.79 dB, and the median SNIR drops from 10.34 dB to 7.72 dB. The worst-case scenario at the edge also shows drops in the Minimum SINR from -0.83 dB to -60.59 dB, indicating severe co-channel interference.

## Zone A – Kimuka Saikeri: Interference Mitigation & Co-existence Optimisation

To mitigate against interference and facilitate coexistence, we modelled on SEAMCAT two scenarios: one where the Inter Site Distance between the NPN site and the Victim MNO Site is 15 kilometres, and the other where Multi-Channel Transmission occurs between the NPN and the VLT MNO sites. We present these mitigation results in the subsequent section.

### Strategy 1: Inter-site distance of 15KM between the NPN site and the Victim MNO Site



Kimuka Saikeri Strategy 1 Mitigated Coexistence Scenario Network Layout

| Victim Results                | ILT Link Results      |
|-------------------------------|-----------------------|
| Average bitrate loss : 5.824% | Sub-carrier ratio 0.2 |
| Sub-carrier ratio 1.0         |                       |

After considering the Inter Site Distance of 15 kilometres between the NPN site and the Victim MNO site as shown in Figure 54, the Average bitrate loss decreases to 5.824%, Table 23. This value falls within the maximum allowable degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system which is 5%. Consequently, this report infers that the two systems are compatible and can guarantee seamless coexistence within the reference cluster.

After considering the Inter Site Distance of 15KM between the NPN site and the Victim MNO site, the average dRSS remains relatively unchanged compared to the scenario where interference mitigation and coexistence optimisation are not taken into account. In fact, the average non-interfered bitrate and the non-interfered SINR in this scenario are not significantly different from the baseline coexistence study discussed earlier, prior to interference mitigation and coexistence optimisation.

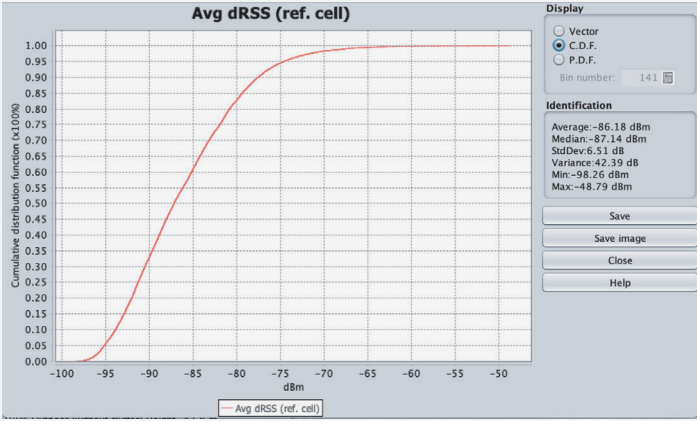


Figure 57: Zone A – Kimuka Saikeri:  
Mitigate Strategy 1 Co-Existence Average dRSS Results

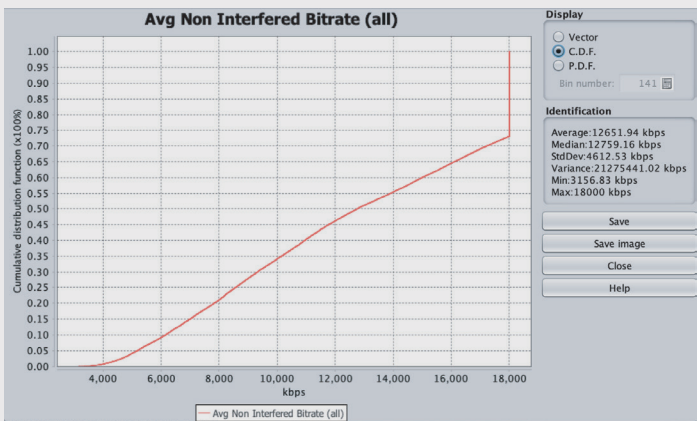


Figure 58: Zone A – Kimuka Saikeri:  
Mitigate Strategy 1 Co-Existence Average Non-Interfered Birate results

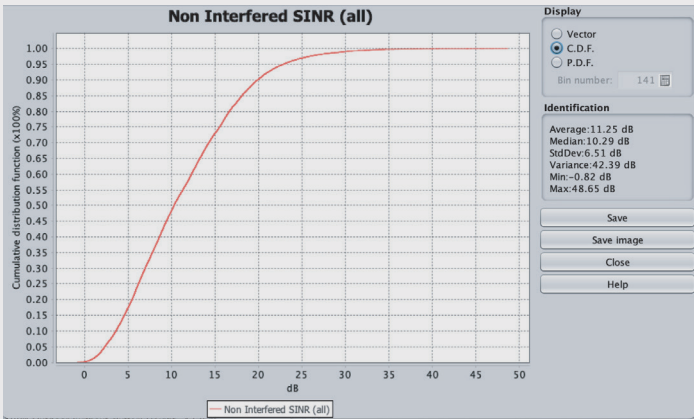


Figure 59: Zone A – Kimuka Saikeri:  
Mitigate Strategy 1 Co-Existence Non-Interfered SINR results

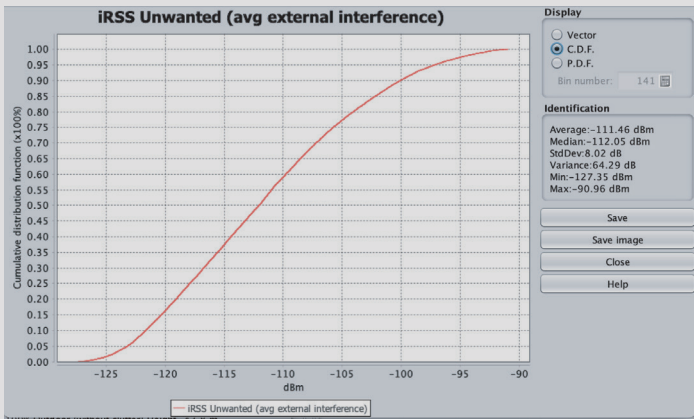


Figure 60: Zone A – Kimuka Saikeri:  
Mitigate Strategy 1 Co-Existence Inteferece iRSS results

After considering the Inter Site Distance of 15 kilometres between the NPN site and the Victim MNO site, the interfering Received Signal Strength significantly decreases from -99.19 dBm in the baseline to -111.46 dBm when the inter site distance is 15 kilometres. This represents an improvement as shown in Figure 58. The median Unwanted Interference (iRSS) also decreases from -101.10 dBm to -112.05 dBm. The worst case scenario also decreases from -98.27 dBm in the non-interference case to -117.46 dBm to -127.35 dBm. All these improvements indicate an improved link with minimal interference from the ILT.



When considering the Inter Site Distance of 15KM between the NPN site and the Victim MNO site, the average bitrate also indicates an improved link. Figure 59 shows that this value increases from 10.1Mbps to 12.1Mbps. Furthermore, the worst-case scenario improves from a bitrate of 0kbps to 1Mbps. Additionally, from the simulation runs, after considering the Inter Site Distance of 15KM between the NPN site and the Victim MNO site, more than 30% of the scenarios could attain the maximum bitrate during transmission of 18Mbps. This represents an improvement from the 19% achieved in the interfered link without any interference mitigation or co-existence optimisation strategies implemented.

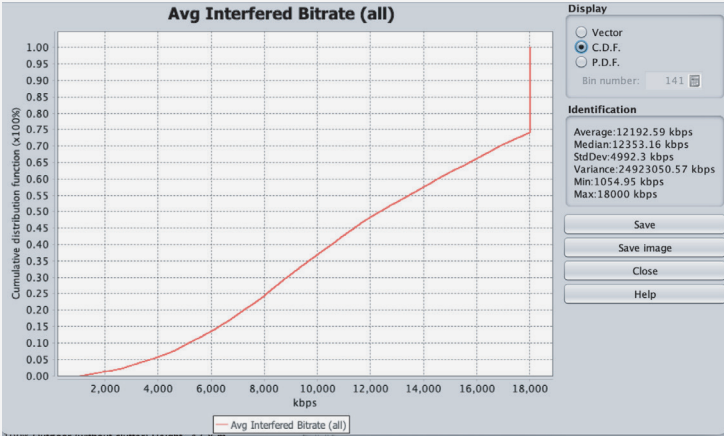


Figure 61: Zone A – Kimuka Saikeri:  
Mitigate Strategy 1 Co-Existence Inteferece Average Bitrate results

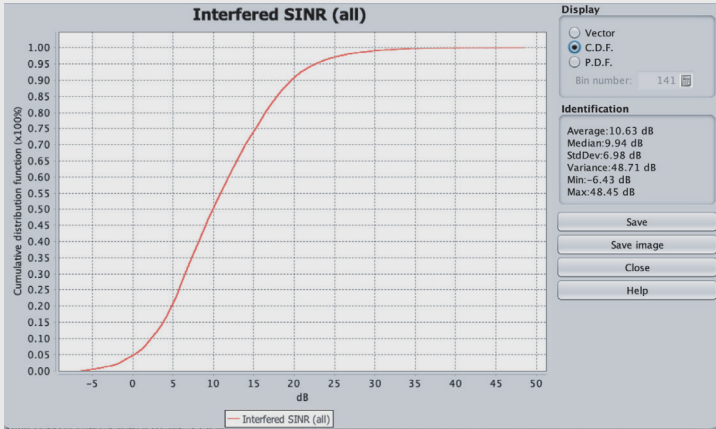


Figure 62: Zone A – Kimuka Saikeri:  
Mitigate Strategy 1 Co-Existence Inteferece Interefed SINR results

The interfered SINR improves significantly when considering an Inter Site Distance of 15 km between the NPN site and the Victim MNO site. The previous average SINR of 6.79 dB increases to 10.63 dB, while the median SINR rises from 7.72 dB to 9.94 dB as captured in Figure 60. Even at the edge of the cell, the worst-case scenario shows a remarkable improvement in SINR from -60.59 dB to -6.43 dB. These enhanced SINR values indicate that the link post Interference Mitigation and Co-existence Optimisation strategies have been successfully implemented. Furthermore, the two systems demonstrate compatibility, ensuring seamless coexistence within the reference cluster.

## Strategy 2: Multi-Channel Transmission between NPN and VLT MNO

The second Interference Mitigation and Coexistence Optimisation strategy employed Multi-Channel Transmission between NPN and VLT MNO. This strategy retained the original inter-site distance of 8.2455 km. However, the NPN transmitted at a centre frequency of 1825 MHz. Additionally, we expanded the MNOs receiver blocking response upper limit to  $\pm 30$  MHz at 50 dB and the Saikeri ILT transmitter out-of-band emission limits to  $\pm 35$  MHz at -65 dB to ensure experiment fidelity. The outcomes are as follows in Table 25.

| Victim Results                | ILT Link Results      |
|-------------------------------|-----------------------|
| Average bitrate loss : 0.291% | Sub-carrier ratio 0.2 |
| Sub-carrier ratio 1.0         |                       |

Table 18: Zone A Kimuka Saikeri Strategy 2 Mitigated Coexistence Results

After considering Multi-channel Transmission between NPN and VLT MNO, the Average bitrate loss decreases to 0.291%. This represents minimal interference and falls within the permissible degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system. Consequently, the two systems are compatible and can ensure seamless coexistence within the reference cluster.

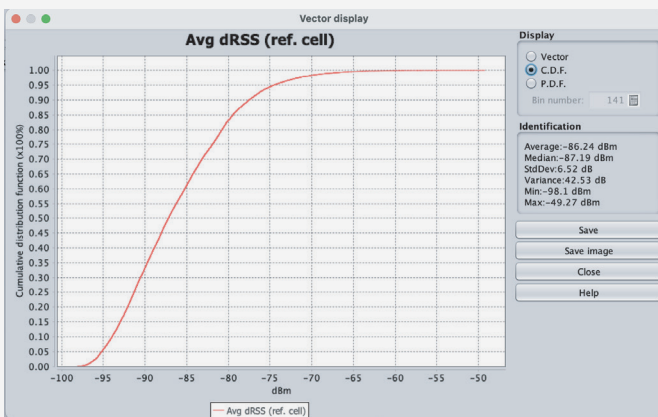


Figure 63: Zone A – Kimuka Saikeri:  
Mitigate Strategy 2 Co-Existence Average dRSS

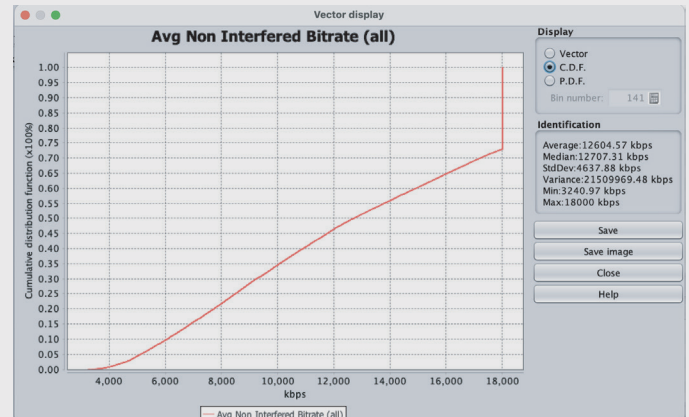


Figure 64: Zone A – Kimuka Saikeri:  
Mitigate Strategy 2 Co-Existence Average Non-Interfered Birate

After considering Multi-Channel Transmission between NPN and VLT MNO, the average dRSS remains relatively unchanged compared to the scenario where interference mitigation and Co-existence Optimisation are not considered. Similarly, the average Non-interfered bitrate and the non-interfered SINR in this scenario are not significantly different from the baseline coexistence study discussed earlier, prior to considering interference mitigation and Co-existence Optimisation as shown in Figures 62 and 63.

In contrast, when considering Multi-Channel Transmission between NPN and VLT MNO as shown in Figure 64, the interfering Received Signal Strength further decreases, from -111.46 when the inter site distance is 15 km to -150.56 dBm. This represents an even more significant improvement. The median Unwanted Interference (iRSS) also drops from -112.05 dBm to -152.56 dBm. The worst-case scenario also decreases further from -127.35 dBm to -168.95 dBm. All these improvements indicate an enhanced link with minimal interference from the ILT when Multi-Channel Transmission between NPN and VLT MNO is considered.

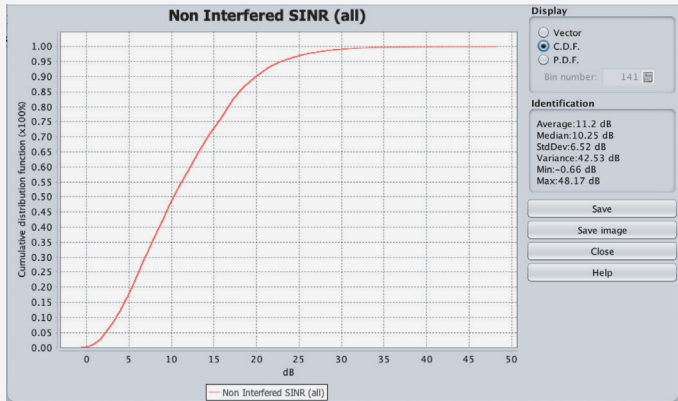


Figure 65: Zone A – Kimuka Saikeri:  
Mitigate Strategy 2 Co-Existence Non-Interfered SINR results

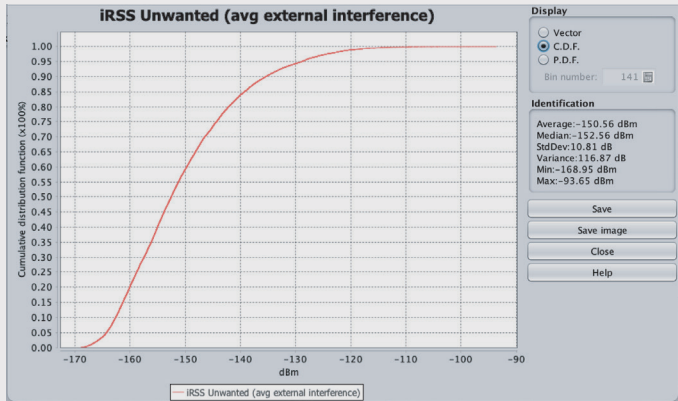


Figure 66: Zone A – Kimuka Saikeri:  
Mitigate Strategy 2 Co-Existence Interference iRSS results

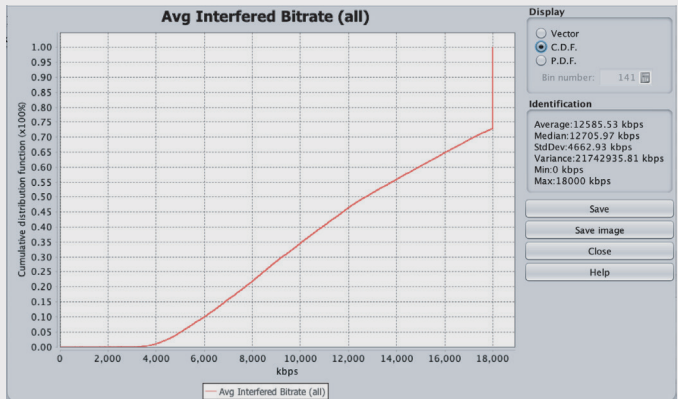


Figure 67: Zone A – Kimuka Saikeri:  
Mitigate Strategy 2 Co-Existence Interference Average Bitrate results

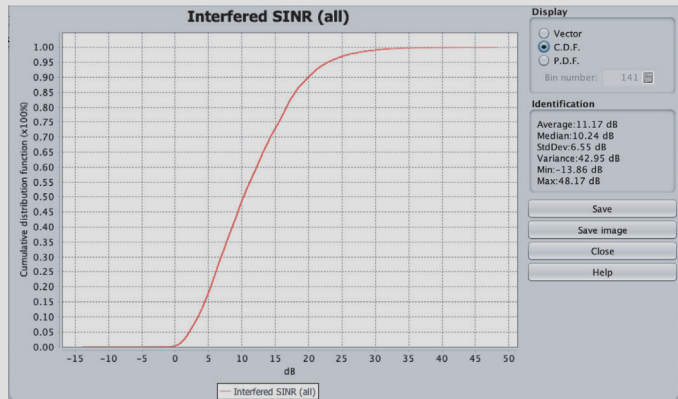


Figure 68: Zone A – Kimuka Saikeri:  
Mitigate Strategy 2 Co-Existence Interference Interfered SINR results

When considering Multi-Channel Transmission between NPN and VLT MNO, the average bitrate demonstrates indications of an improved link as seen in Figure 65. This value increases from 12.1Mbps when the Inter Site Distance between the NPN site and Victim MNO Site is 15KM to 12.5Mbps. Furthermore, more than 30% of the scenarios can attain the maximum bitrate during transmission at 18Mbps. Conversely, less than 1% of the scenarios transmit at 0.0Kbps. In general, the coexistence strategy of Multi-Channel Transmission between NPN and VLT MNO demonstrates an improvement in the average bitrate.



## Zone B-1- Kisamis Corner Co-existence Study

| "Parameters Site (s)"    | Safaricom Site 431 LTE (VLT) | Olepolos NPN Site (ILT) | Kisamis NPN Site (ILT) | Shams Camp NPN Site (ILT) |
|--------------------------|------------------------------|-------------------------|------------------------|---------------------------|
| Power                    | 3W                           | 1W                      | 1W                     | 1W                        |
| Frequency                | 1800 MHZ                     | 1800 MHZ                | 1800 MHZ               | 1800 MHZ                  |
| TX Gain                  | 15.54 dBi                    | 3.5dBi                  | 3.5dBi                 | 3.5dBi                    |
| EIRP                     | 92.70885W                    | 2.238721W               | 2.238721W              | 2.238721W                 |
| losses                   | 0.5db                        | 0                       | 0                      | 0                         |
| Antenna Height           | 45m                          | 20m                     | 20m                    | 20m                       |
| TX/RX Bandwidth          | 10MHZ                        | 10MHz                   | 10MHz                  | 10MHz                     |
| Propagation Model        | ITU-R-P452-18                | ITU-R-P452-18           | ITU-R-P452-18          | ITU-R-P452-18             |
| Technology               | LTE FDD                      | LTE FDD                 | LTE FDD                | LTE FDD                   |
| Sub Carrier Spacing      | 15KHz                        | 15KHz                   | 15KHz                  | 15KHz                     |
| Total RBs                | 50                           | 50                      | 50                     | 50                        |
| Total Subcarriers        | 600                          | 600                     | 600                    | 600                       |
| RB bandwidth             |                              | 180KHz                  | 180KHz                 | 180KHz                    |
| RX noise figure          | 7 dB                         | 7 dB                    | 7 dB                   | 7 dB                      |
| Minimum Coupling loss    | 70 dB                        | 70 dB                   | 70 dB                  | 70 dB                     |
| Handover Margin          | 1.5 dB                       | 1.5 dB                  | 1.5 dB                 | 1.5 dB                    |
| Standard Disensitization | 6 dB                         | 6 dB                    | 6 dB                   | 6 dB                      |
| Target I/N               | -6 dB                        | -6 dB                   | -6 dB                  | -6 dB                     |
| Antenna Radiation        | Isotropic                    | Isotropic               | Isotropic              | Isotropic                 |
| Antenna Pattern          |                              | ITU-R F.1336            | ITU-R F.1336           | ITU-R F.1336              |
| Antenna Arrays TX/RX     | 1/1                          | 1/1                     | 1/1                    | 1/1                       |
| Antenna Tilt             | 140 degrees                  | 0                       | 0                      | 0                         |
| Activity Uplink          | 100%                         | 100%                    | 100%                   | 100%                      |
| Activity Downlink        | 100%                         | 100%                    | 100%                   | 100%                      |
| TX Clutter               | Open-Rural                   | Open-Rural              | Open-Rural             | Open-Rural                |
| RX Clutter               | Open-Rural                   | Open-Rural              | Open-Rural             | Open-Rural                |
| Relative Distance to VTL | NA                           | 6.341km                 | 3.42km                 | 6.0372km                  |
| Path Azimuth to VLT      | NA                           | 235.4                   | 270                    | 183.2                     |

# Zone B-1- Kisamis Corner: Unmitigated Co-Existence Baseline

In Zone-B-1, Kisamis Corner Safaricom LTE Site 431 is the victim, while Olepolos NPN, Kisamis NPN and Shams Camp NPN Sites are the interferers. The network layout shown in Figure 55 represents this scenario, based on the coexistence parameters outlined in the preceding table.

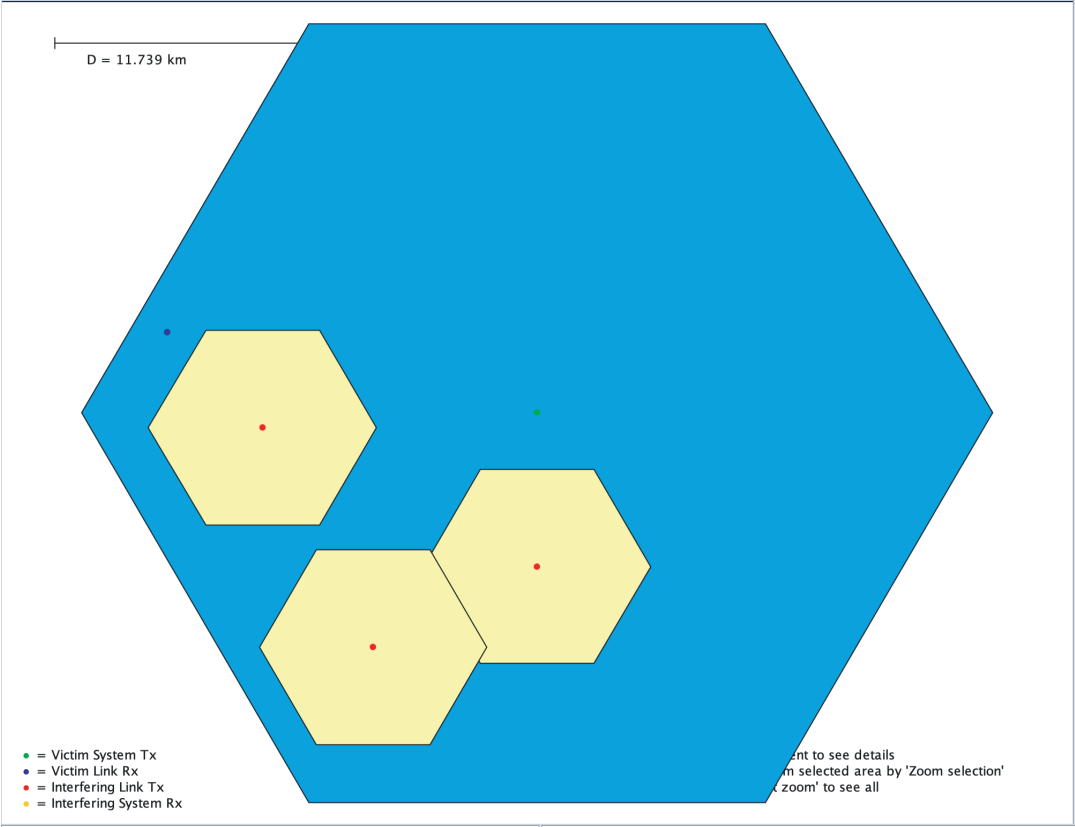


Figure 69: Zone B-1 Kisamis Corner Unmitigated Coexistence Scenario Network Layout

| Victim Results                | ILT 1, 2, 3Link Results |
|-------------------------------|-------------------------|
| Average bitrate loss : 57.08% | Sub-carrier ratio 0.2   |
| Sub-carrier ratio 1.0         |                         |

Table 20: Zone B-1 – Kisamis Corner: Unmitigated Co-Existence Baseline Results

The average bitrate loss in this scenario is 57.08%, which exceeds the desired maximum allowable degradation of 5% for Average Bitrate Loss in the LTE system. This indicates that the two systems are incompatible and cannot guarantee seamless coexistence in the reference cluster.

As shown in Figure 68. When no mitigation is considered, the victims cell records an average dRSS of -85.3 dBm, with maximum values of -44.68 dBm and minimum values of -98.07 dBm at the cell edge as the worst-case scenario. Less than 5% of the simulated values were below the receiver's noise floor of -96.77 dBm. This indicates that the modelled victim cell has adequate reception without interference from the 3 NPN sites.

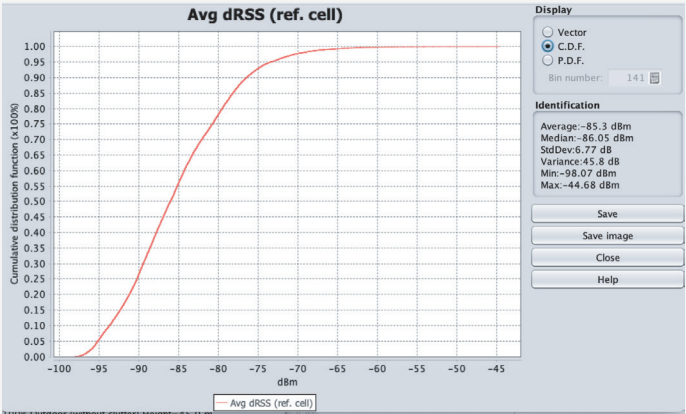


Figure 70: Zone B-1 – Kisamis Corner Saikeri:  
Unmitigated Co-Existence Average dRSS Results

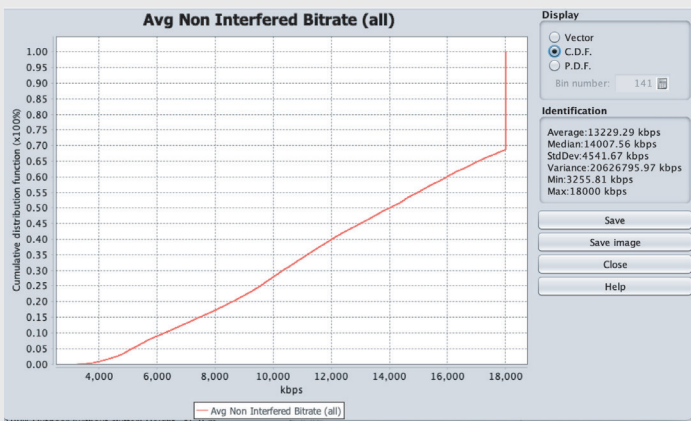


Figure 71: Zone B-1 – Kisamis Corner:  
Unmitigated Co-Existence Average Non-Interfered Bitrate Results

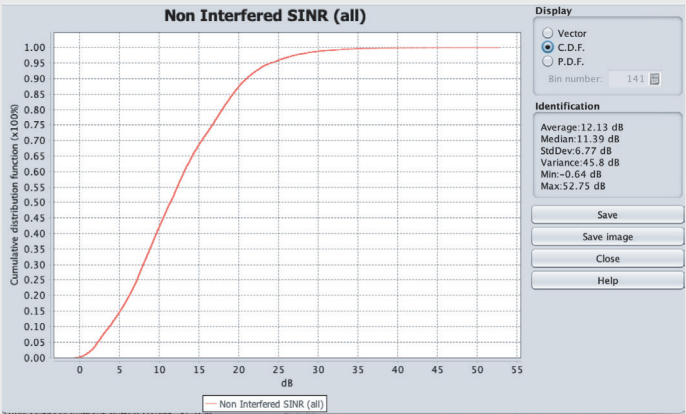


Figure 72: Zone B-1 – Kisamis Corner:  
Unmitigated Co-Existence Average Non-Interfered SINR Results

As seen in Figure 69, the Safaricom Victim system in Zone B-1 – Kisamis Corner achieved an average bitrate of 13.2 Mbps. The minimum bitrate in the worst-case scenarios for this run was 3.25 Mbps. Approximately 32% of the simultaneous events attain the maximum bitrate of 18 Mbps.

The link quality of the non-interfered victim system exhibits an average of 12.13 dB and a median SINR of 11.39 dB. At the extreme edge, as presented in Figure 70, the minimum SINR recorded is -0.64 dB, while the maximum SINR recorded SINR is 57.75 dB.



## Zone B-1- Kisamis Corner Unmitigated Co-Existence Inference

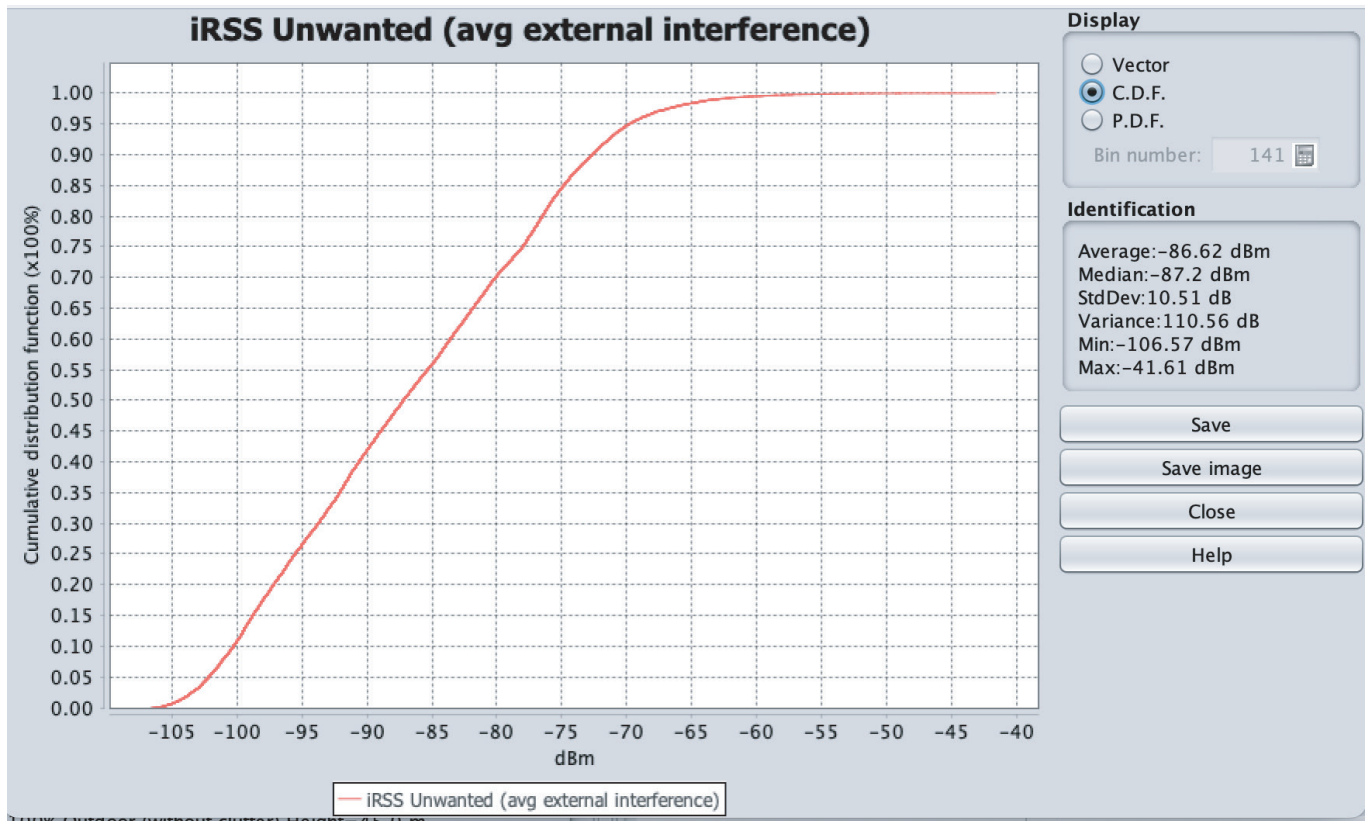


Figure 73: : Zone B-1- Kisamis Corner: Unmitigated Co-Existence Interference iRSS Results

The average interfering Received Signal Strength (iRSS) leakage into the victim's receiver, and the median Unwanted Interference (iRSS) is -86.62 dBm and -87.2 dBm, respectively, see Figure 71. These values are almost equal to the average dRSS, which was -85.3 dBm in the non-interfered scenario. This indicates that the 3NPNs are almost overpowering the receivers served by the MNO site. The worst-case scenario is -106.57 dBm. In the interfering scenario, the ILT leaks into the victim's receiver with a signal strength of -41.61 dBm, which is slightly higher than the victim's maximum values of -44.68 dBm. This indicates severe interference from the 3 NPNs as ILT, causing performance degradation and an average bitrate loss of 57.08% shown in Table 26.

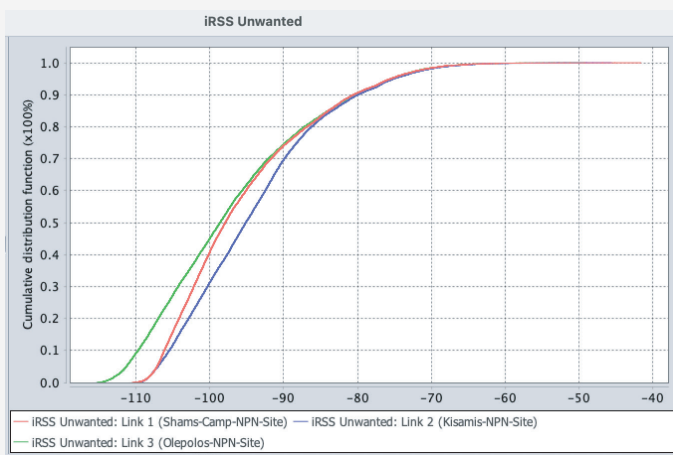


Figure 74: Zone B-1- Kisamis Corner:  
Unmitigated Co-Existence Inference Individual iRSS Results from 3 NPN sites

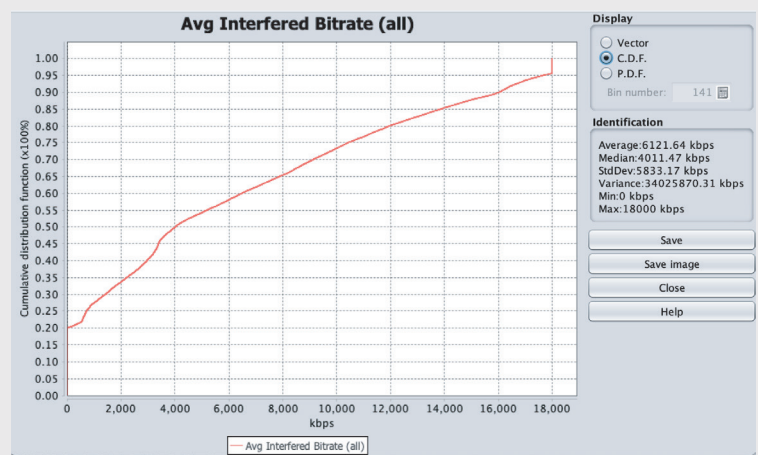


Figure 75: Zone B-1- Kisamis Corner:  
Unmitigated Co-Existence Average Interfered Bitrate Results

In contrast, Figure 72 indicates that Kisamis NPN site is the most potent interferer, with 50% of its interfering signal iRSS instances being above -95 dBm. This observation is consistent with this study because Kisamis NPN is the closest NPN site to the MNO's victim site, with a distance of only 3.42 km to the VLT.

When the system is interfered with by the 3 interfering links from the 3 NPNs at Olepolos, Shams Camp and Kisamis, the average bitrate drops to 6.1 Mbps with a higher standard deviation as shown in Figure 73. On the other hand, the worst-case scenario reports a bitrate of 0 kbps. This means that in the worst case, the receiver and transmitter could exchange no data despite being connected due to interference from the 3 ILTs. Additionally, with interference from the 3 ILTs, less than 5% of the scenarios could attain the maximum bitrate during the transmission of 18 Mbps.

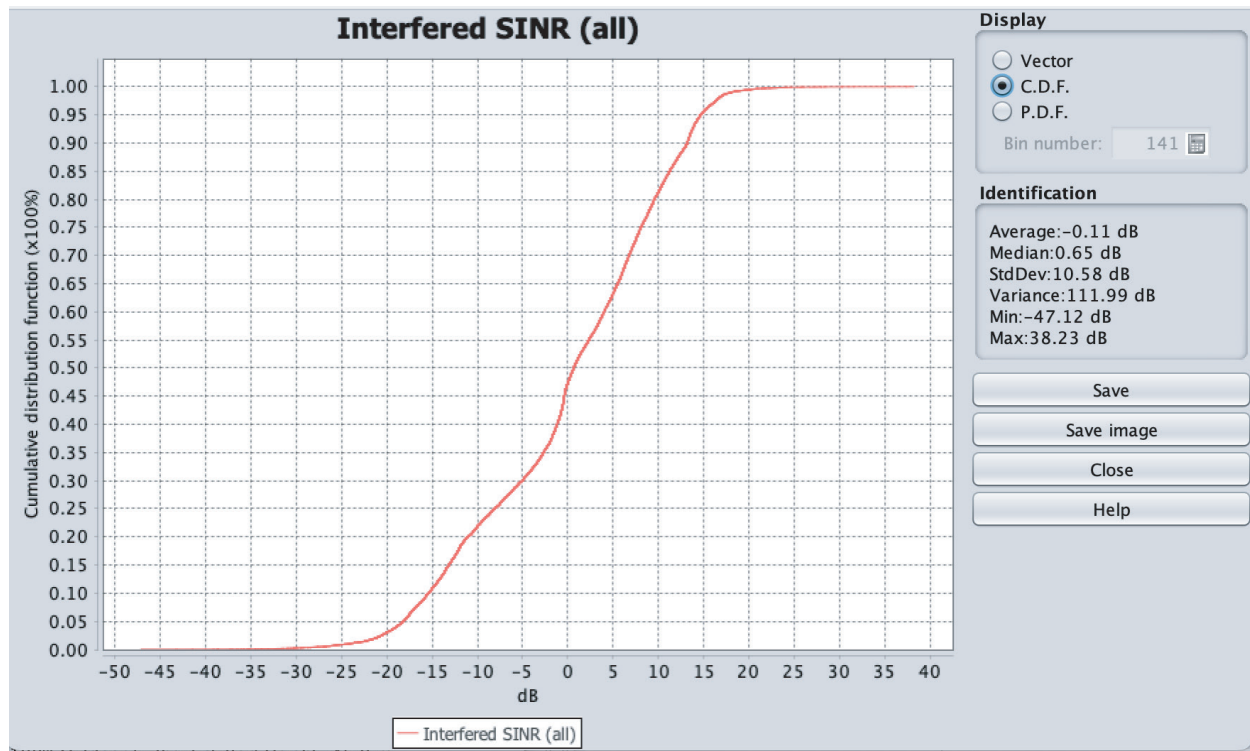


Figure 76: Zone B-1- Kisamis Corner: Unmitigated Co-Existence Interfered SINR Results

Conversely, compared with the non-interfered SINR, the link quality of the interfered victim system deteriorates sharply. The average SINR drops from 12.13 dB to -0.11 dB, and the median SINR drops from 11.39 dB to -0.65 dB as shown in Figure 74. This is a sharp decline and is indicative of the massive interference from the 3 NPN sites on the VLT. The worst-case scenario at the edge also shows drops in the Minimum SINR from -0.64 dB to -41.12 dB. The maximum recorded SINR also drops from 57.75 dB to 38.23dB. All these SINR figures indicate severe co-channel interference between the 3 NPN sites and Safaricom's VLT.

## Zone B-1- Kisamis Corner Interference Mitigation & Co-existence Optimisation

To mitigate against interference and facilitate coexistence, we modelled on SEAMCAT two scenarios: one where the Inter Site Distance between the 3 NPN sites and the Victim MNO Site is 15 kilometres, and the other where Multi-Channel Transmission occurs between the NPN and the VLT MNO sites. We present these mitigation results in the subsequent section.

### Strategy 1: Inter-site distance of 15KM between the 3 NPN sites and the Victim MNO Site

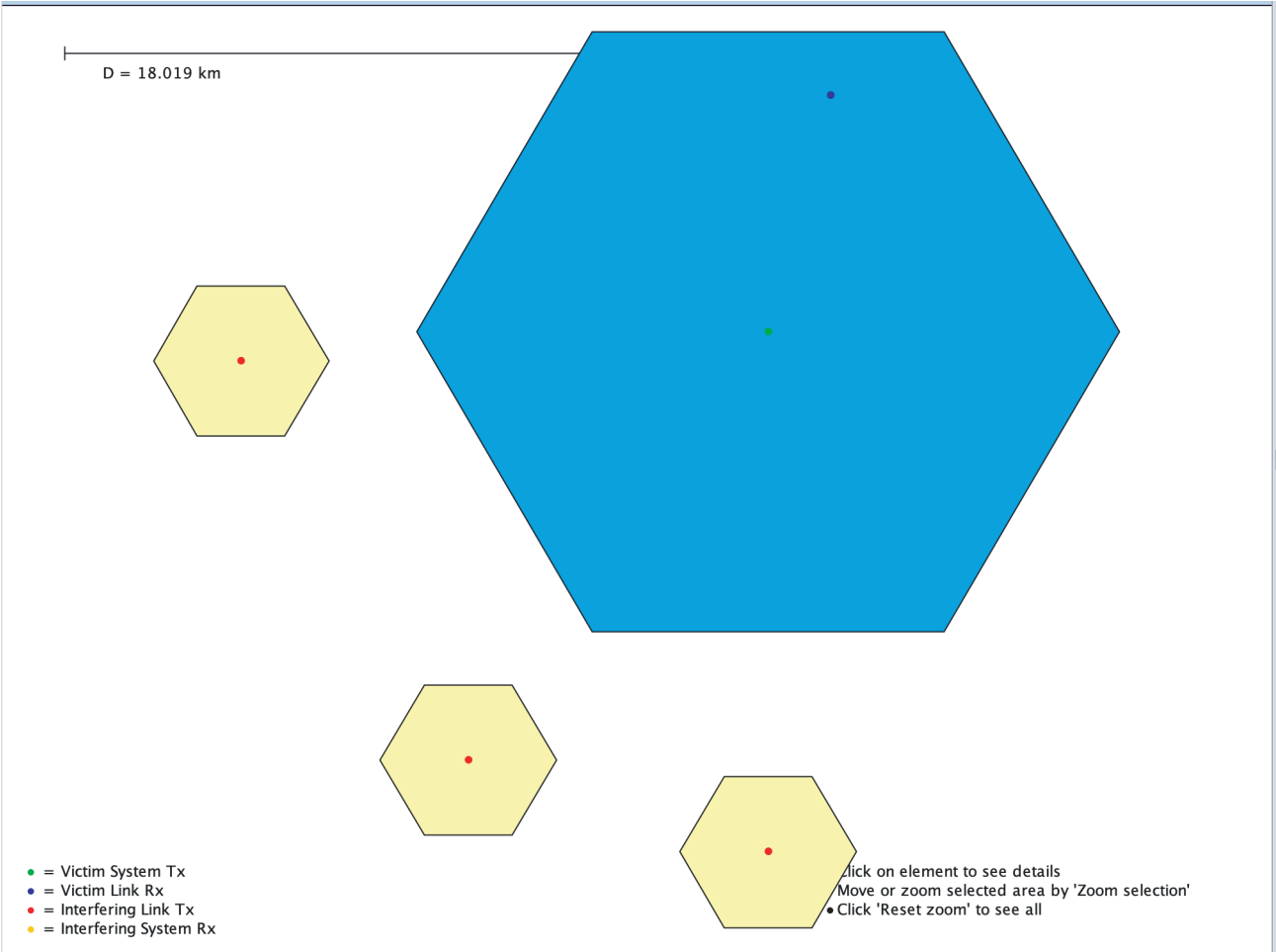


Figure 77: Zone B-1- Kisamis Corner Strategy 1 Mitigated Coexistence Scenario Network Layout

| Victim Results               | ILT 1, 2, 3Link Results |
|------------------------------|-------------------------|
| Average bitrate loss : 12.7% | Sub-carrier ratio 0.2   |
| Sub-carrier ratio 1.0        |                         |



After considering the Inter Site Distance of 15 kilometres between the 3 NPN sites and the Victim MNO site, as shown in Figure 75, the average bitrate loss decreases to 12.7% as shown in Table 27. This value is still higher than the maximum allowable degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system of 5%. Consequently, the two systems are not compatible and cannot guarantee seamless coexistence within the reference cluster. Other coexistence mechanisms need to be considered.

The average dRSS remains relatively unchanged compared to the scenario where interference mitigation and coexistence optimisation are not taken into account. In fact, the average non-interfered bitrate and the non-interfered SINR in this scenario are not significantly different from the baseline coexistence study discussed earlier, prior to interference mitigation and coexistence optimisation Figures 76, 77 and 78 show this.

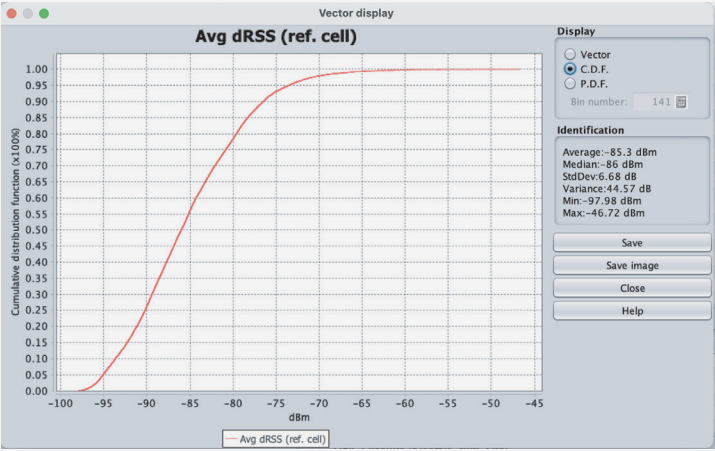


Figure 78: Zone B-1- Kisamis Corner: Mitigation Strategy 1 Co-Existence Average dRSS

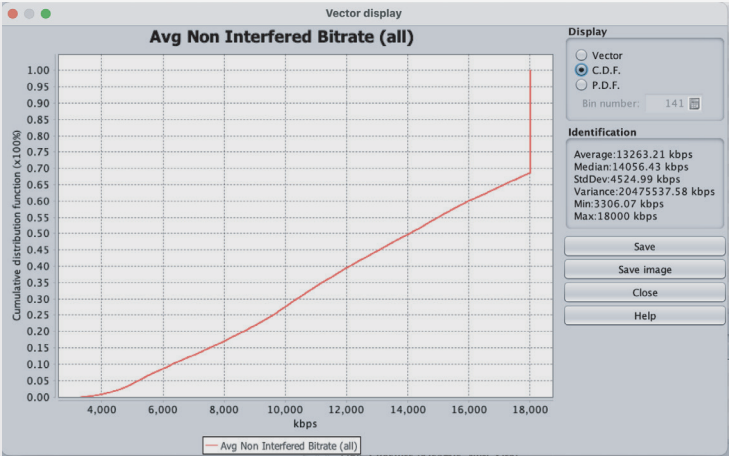


Figure 79: Zone B-1- Kisamis Corner: Mitigation Strategy 1 Co-Existence Average Non-Interfered Birate

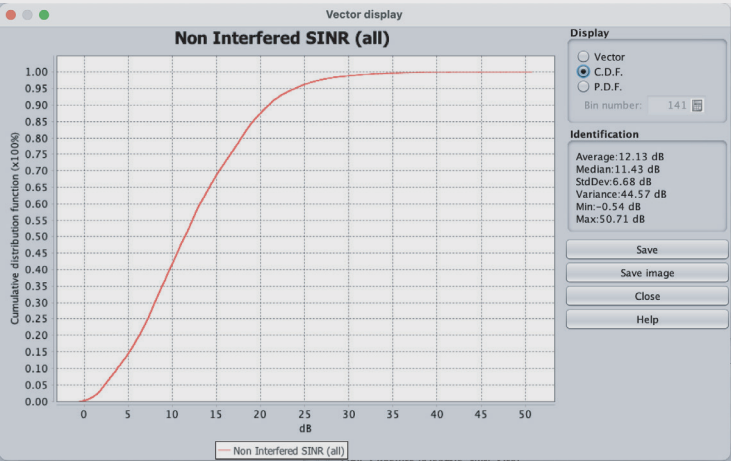


Figure 80: Zone B-1- Kisamis Corner: Mitigation Strategy 1 Co-Existence Average Non-Interfered SINR results

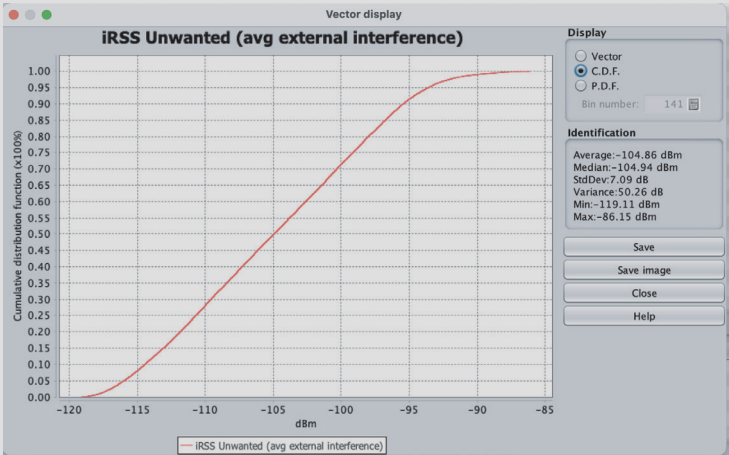


Figure 81: Zone B-1- Kisamis Corner: Mitigate Strategy 1 Co-Existence Interference iRSS result

After considering the Inter Site Distance of 15 kilometres between the 3 NPN sites and the Victim MNO site, the interfering Received Signal Strength significantly decreases from -86.62 dBm to -104.86 and the median Unwanted Interference (iRSS) also decreases from -87.2 dBm to -104.94. The worst-case scenario also decreases from -98.07 dBm in the non-interference case to -106.57 dBm to -119.11 dBm. All these improvements shown in Figure 79 indicate an improved link with minimal interference from the ILT. However, these improvements are not enough to ensure that the minimal interference falls within the permissible degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system, which is 5% average bitrate loss.

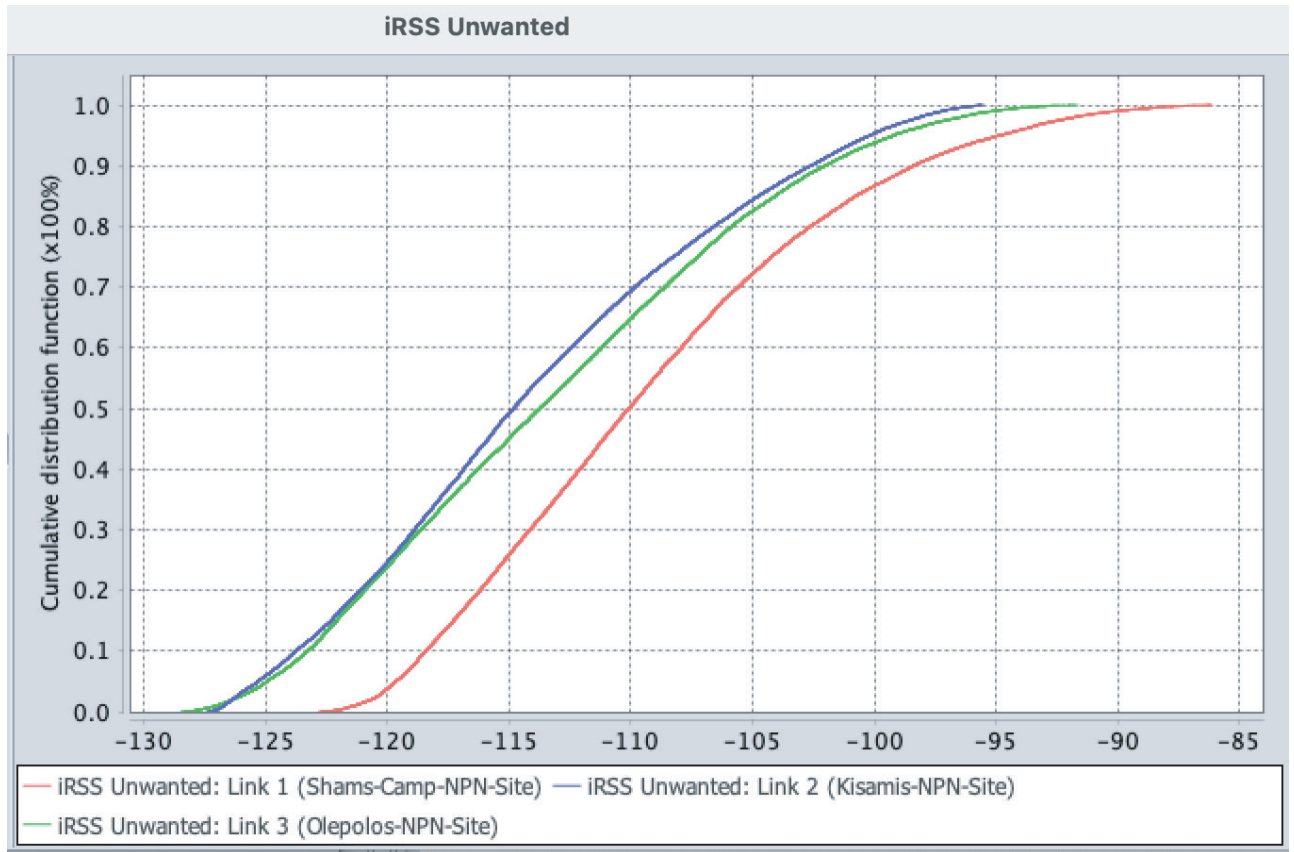


Figure 82: Zone B-1- Kisamis Corner: Mitigated Strategy 1 Co-Existence Interference Individual iRSS Results from 3 NPN site

In contrast, Figure 80 indicates that Shams Camp NPN site is the most potent interferer, with close to 95% of its interfering signal iRSS instances being above -95 dBm. This observation is consistent with this study because with the mitigation strategy of increasing the inter-site distance to 15 km between the 3 NPN sites and the Victim MNO site, Shams Camp NPN ended up being the closest NPN site to the MNO's victim site, as shown in Figure 75.

When considering the Inter Site Distance of 15KM between the 3 NPN sites and the Victim MNO site, the average bitrate also indicates an improved link as seen in Figure 81. This value increases from 6.1 Mbps to 12.1Mbps. Additionally, from the simulation runs, after considering the Inter Site Distance of 15KM between the 3 NPN sites and the Victim MNO site, more than 30% of the scenarios could attain the maximum bitrate during transmission of 18Mbps. This represents an improvement from the 5% achieved in the interfered link without any Interference Mitigation or Co-existence Optimisation strategies implemented.

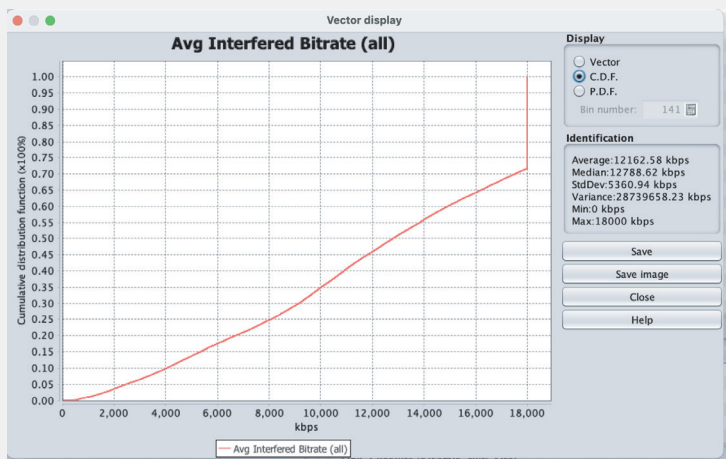


Figure 83: Zone B-1- Kisamis Corner:  
Mitigation Strategy 1 Co-Existence Interference Average Bitrate results

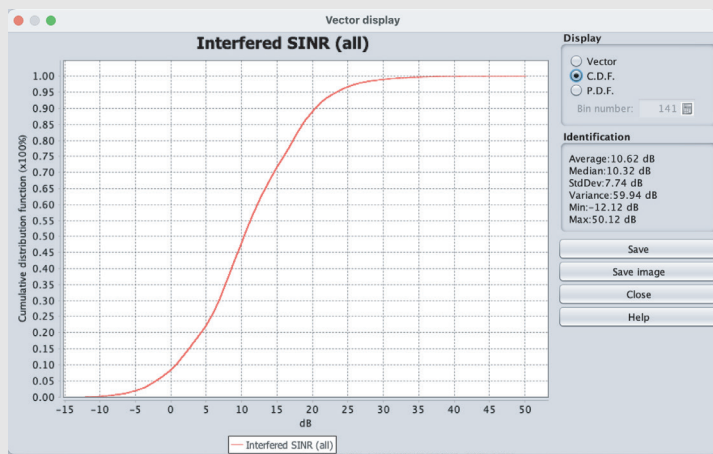


Figure 84: Zone B-1- Kisamis Corner:  
Mitigate Strategy 1 Co-Existence Interference Interfered SINR results

The interfered SINR improves significantly when considering an Inter Site Distance of 15 km between the NPN site and the Victim MNO site. The previous average SINR of -0.11 dB increases to 10.62 dB, while the median SINR rises from -0.65 dB to 10.32 dB. Even at the edge of the cell, the worst-case scenario shows a remarkable improvement in SINR from -41.12 dB to -12.12 dB. These enhanced SINR values shown in Figure 82 indicate that the link improved post interference mitigation and co-existence optimisation strategies have been successfully implemented. However, the two systems are still not compatible and cannot guarantee seamless coexistence within the reference cluster, given the current conditions.



Strategy 2: Multi-Channel Transmission between NPN and VLT MNO

The second Interference Mitigation and Coexistence Optimisation strategy employed Multi-Channel Transmission between NPN and VLT MNO. This strategy retained the original inter-site distances for all the 3 NPN sites. However, the 3 NPNs were transmitting at centre frequencies of 1825 MHz. Additionally, we expanded the MNOs receiver blocking response upper limit to +/-30 MHz at 50 dB and the 3 NPN ILT transmitters' out-of-band emission limits to +/-35 MHz at -65 dB to ensure experiment fidelity. The outcomes are as shown in Table 28.

| Victim Results                | 3 NPNs ILT Link Results |
|-------------------------------|-------------------------|
| Average bitrate loss : 0.519% | Sub-carrier ratio 0.2   |
| Sub-carrier ratio 1.0         |                         |

Table 22: Zone B-1- Kisamis Corner: Mitigate Strategy 2 Co-Existence Results

After considering Multi-Channel Transmission between the 3 NPNs and VLT MNO, the Average bitrate loss decreases to 0.519%. This represents minimal interference and falls within the permissible degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system. Consequently, the two systems are compatible and can ensure seamless coexistence within the reference cluster.

## Zone B-1- Kisamis Corner: Mitigation Strategy 2 Co-Existence Average dRSS, Average Non-Interfered Birate and Non-Interfered SINR results

After considering Multi-Channel Transmission between the 3 NPNs and VLT MNO, the average dRSS remains relatively unchanged compared to the scenario where interference mitigation and Co-existence Optimisation are not taken into account. Similarly, the average Non-interfered bitrate and the non-interfered SINR in this scenario are not significantly different from the baseline coexistence study discussed earlier, prior to considering interference mitigation and Co-existence Optimisation. Figures 83, 84 and 85 show this.

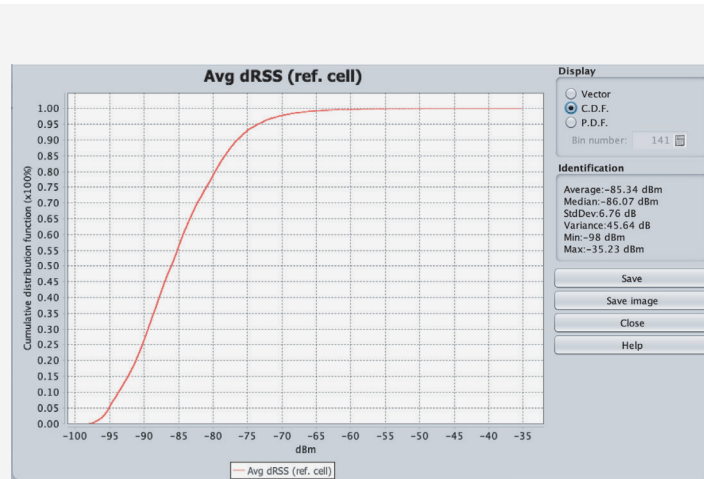


Figure 85: Zone B-1- Kisamis Corner:  
Mitigation Strategy 2 Co-Existence Average dRSS results

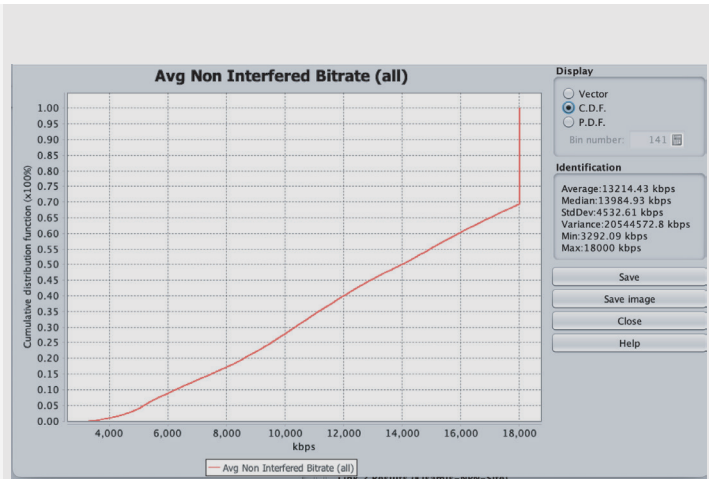


Figure 86: Zone B-1- Kisamis Corner:  
Mitigation Strategy 2 Co-Existence Average Non-Interfered Birate

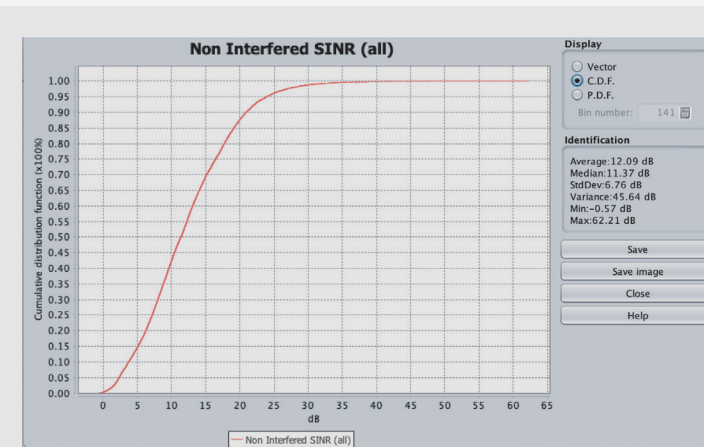


Figure 87: Zone B-1- Kisamis Corner:  
Mitigation Strategy 2 Co-Existence Non-Interfered SINR results

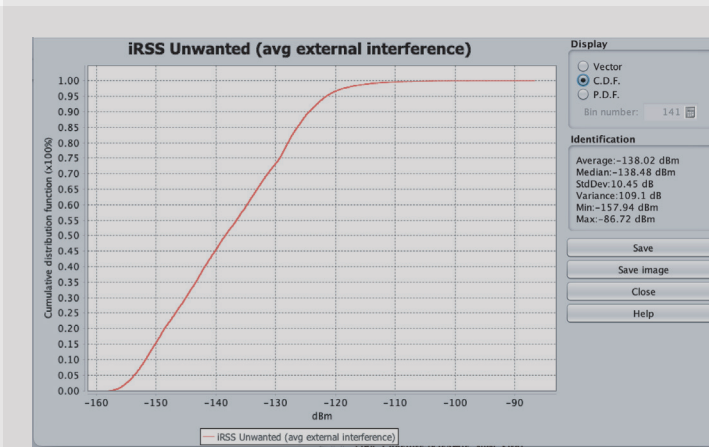


Figure 88: Zone B-1- Kisamis Corner:  
Mitigation Strategy 2 Co-Existence Interference iRSS results

In contrast, when considering Multi-Channel Transmission between the 3 NPNs and VLT MNO, the interfering Received Signal Strength further decreases, from -104.86 dBm when the intersite distance is 15 km to -130.48 dBm. This represents an even more significant improvement. The median Unwanted Interference (iRSS) also drops from -104.94 dBm to -138.48 dBm. The worst-case scenario also decreases further from -119.11 dBm to -157.94 dBm. All these improvements indicate an enhanced link with minimal interference from the ILT when Multi-Channel Transmission between NPN and VLT MNO is considered.

In contrast, Figure 87 indicates that Kisamis NPN site is the most potent interferer, nonetheless. This observation is consistent with this study because Kisamis NPN is the closest NPN site to the MNO's victim site, with a distance of only 3.42 km to the VLT. Only this time the Multi-Channel Transmission between NPN and VLT MNO is considered as a interference mitigation and coexistence strategy

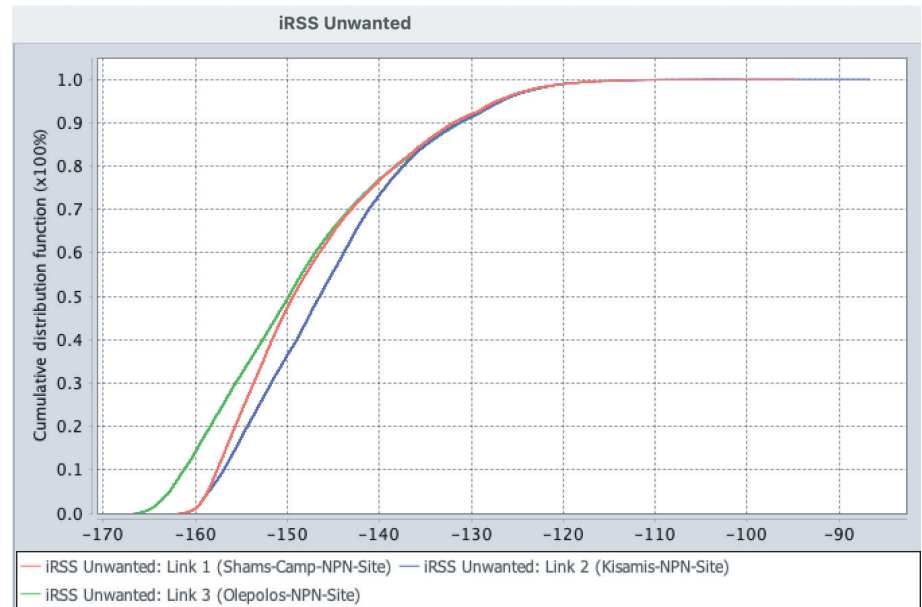


Figure 89: Zone B-1- Kisamis Corner:  
Mitigation Strategy 2 Co-Existence Interference Individual iRSS Results from 3 NPN sites

When considering Multi-Channel Transmission between the 3 NPNs and VLT MNO, the average bitrate as seen in Figure 88 demonstrates indications of an improved link. This value increases from 12.1Mbps when the Inter Site Distance between the NPN site and Victim MNO Site is 15KM to 13.1Mbps. Furthermore, more than 30% of the scenarios can attain the maximum bitrate during transmission at 18Mbps. Conversely, less than 1% of the scenarios transmit at 0.0Kbps. In general, the coexistence strategy of Multi-Channel Transmission between the 3 NPN and VLT MNO demonstrates an improvement in the average bitrate.

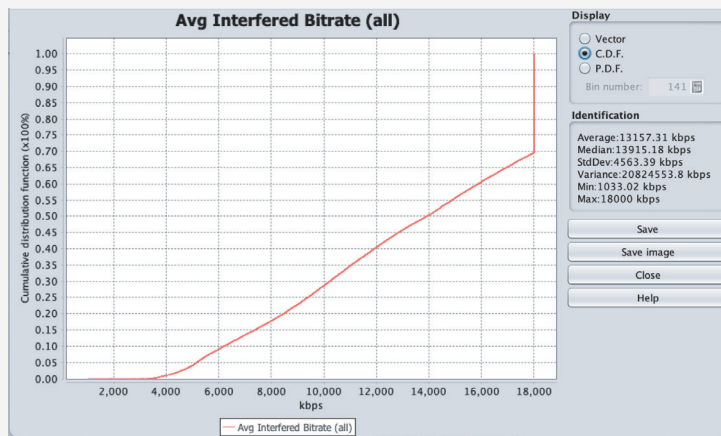


Figure 90: Zone B-1- Kisamis Corner:  
Mitigation Strategy 2 Co-Existence Interference Average Bitrate results

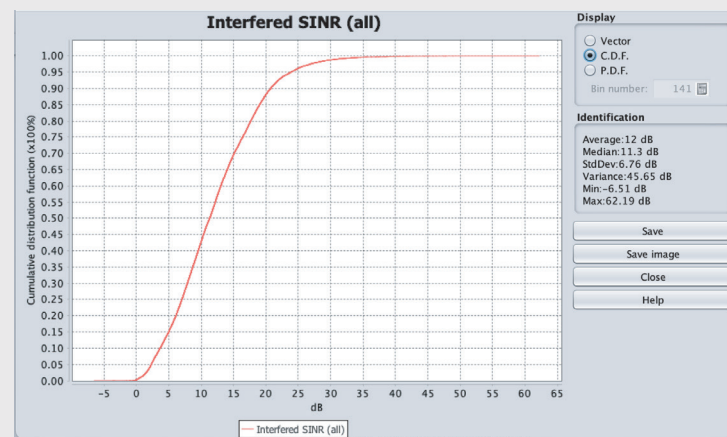


Figure 91: Zone B-1- Kisamis Corner:  
Mitigation Strategy 2 Co-Existence Interference Interfered SINR results

The interfered SINR Multi-Channel Transmission between the 3 NPNs and VLT MNO also improves. The previous average SINR of 10.62 dB has increased to 12 dB. The median SNIR has also increased from 10.32 dB to 11.3 dB. These improvements shown in Figure 89 indicate that the link post interference mitigation and coexistence optimisation strategies have been successfully implemented. The two systems are now compatible and can guarantee seamless coexistence in the reference cluster.



## Zone B-2- Kisamis Market Co-existence Study

| "Parameters Site (s)"         | Safaricom LTE Site 379 (VLT) | Olepolos NPN Site (ILT) | Kisamis NPN Site (ILT) | Shams Camp NPN Site (ILT) |
|-------------------------------|------------------------------|-------------------------|------------------------|---------------------------|
| Power                         | 3W                           | 1W                      | 1W                     | 1W                        |
| Frequency                     | 1800 MHZ                     | 1800 MHZ                | 1800 MHZ               | 1800 MHZ                  |
| TX Gain                       | 15.70 dBi                    | 3.5dBi                  | 3.5dBi                 | 3.5dBi                    |
| EIRP                          | 99.33933W                    | 2.238721W               | 2.238721W              | 2.238721W                 |
| losses                        | 0.5db                        | 0                       | 0                      | 0                         |
| Antenna Height                | 34m                          | 20m                     | 20m                    | 20m                       |
| TX/RX Bandwidth               | 10MHZ                        | 10MHz                   | 10MHz                  | 10MHz                     |
| Propagation Model             | ITU-R-P452-18                | ITU-R-P452-18           | ITU-R-P452-18          | ITU-R-P452-18             |
| Technology                    | LTE FDD                      | LTE FDD                 | LTE FDD                | LTE FDD                   |
| Sub Carrier Spacing           | 15KHz                        | 15KHz                   | 15KHz                  | 15KHz                     |
| Total RBs                     | 50                           | 50                      | 50                     | 50                        |
| Total Subcarriers             | 600                          | 600                     | 600                    | 600                       |
| RB bandwidth                  |                              | 180KHz                  | 180KHz                 | 180KHz                    |
| RX noise figure               | 7 dB                         | 7 dB                    | 7 dB                   | 7 dB                      |
| Minimum Coupling loss         | 70 dB                        | 70 dB                   | 70 dB                  | 70 dB                     |
| Handover Margin               | 1.5 dB                       | 1.5 dB                  | 1.5 dB                 | 1.5 dB                    |
| Standard Disensitization      | 6 dB                         | 6 dB                    | 6 dB                   | 6 dB                      |
| Target I/N                    | -6 dB                        | -6 dB                   | -6 dB                  | -6 dB                     |
| Antenna Radiation             | Isotropic                    | Isotropic               | Isotropic              | Isotropic                 |
| Antenna Pattern               |                              | ITU-R F.1336            | ITU-R F.1336           | ITU-R F.1336              |
| Antenna Arrays TX/RX          | 1/1                          | 1/1                     | 1/1                    | 1/1                       |
| Antenna Tilt                  | 0                            | 0                       | 0                      | 0                         |
| Activity Uplink               | 100%                         | 100%                    | 100%                   | 100%                      |
| Activity Downlink             | 100%                         | 100%                    | 100%                   | 100%                      |
| TX Clutter                    | Open-Rural                   | Open-Rural              | Open-Rural             | Open-Rural                |
| RX Clutter                    | Open-Rural                   | Open-Rural              | Open-Rural             | Open-Rural                |
| Relative Distance to VTL (KM) | NA                           | 2.724                   | 2.340                  | 6.747                     |
| Path Azimuth to VLT (degrees) | NA                           | 172.41                  | 67.38                  | 136.08                    |

Zone B-2- Kisamis Market Unmitigated Co-Existence Baseline

In Zone-B-2, Kisamis Market Safaricom LTE Site 379 is the victim, while Olepolos NPN, Kisamis NPN and Shams Camp NPN Sites are the interferers. The network layout shown in Figure 90 represents this scenario, based on the coexistence parameters outlined in the preceding Table 23.

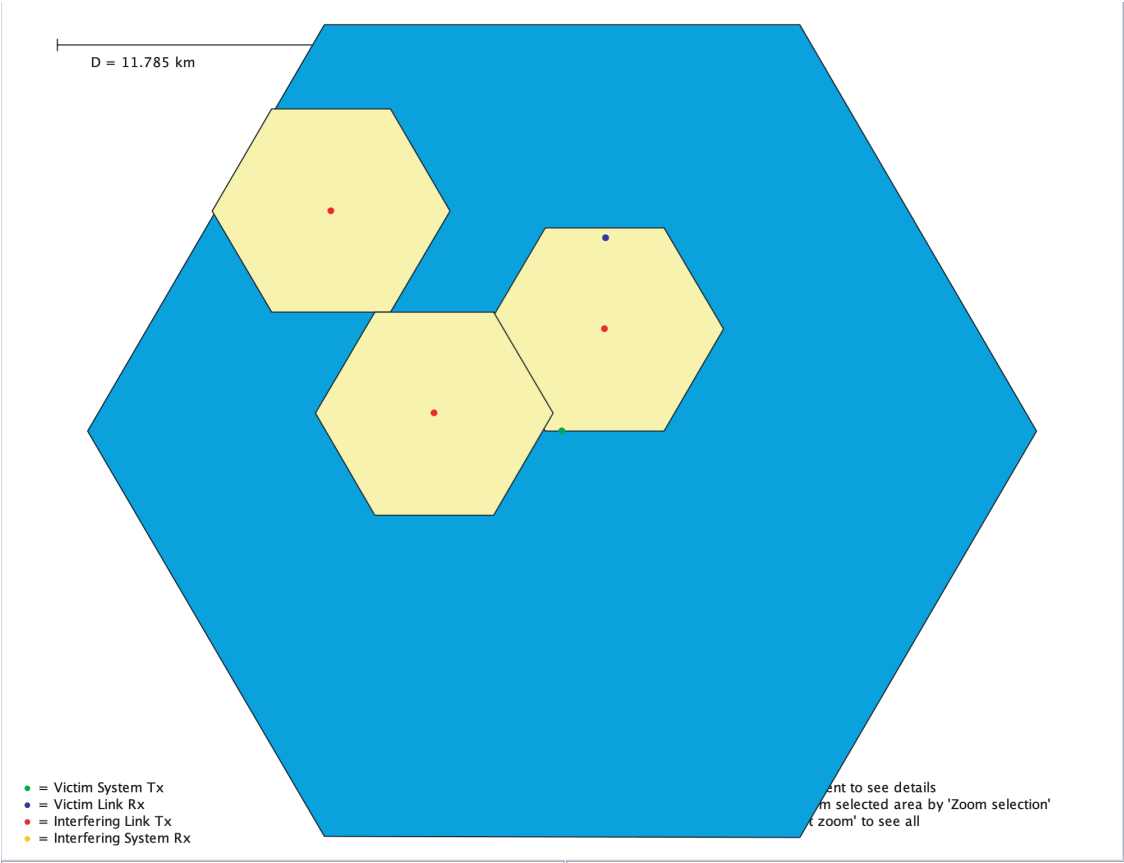
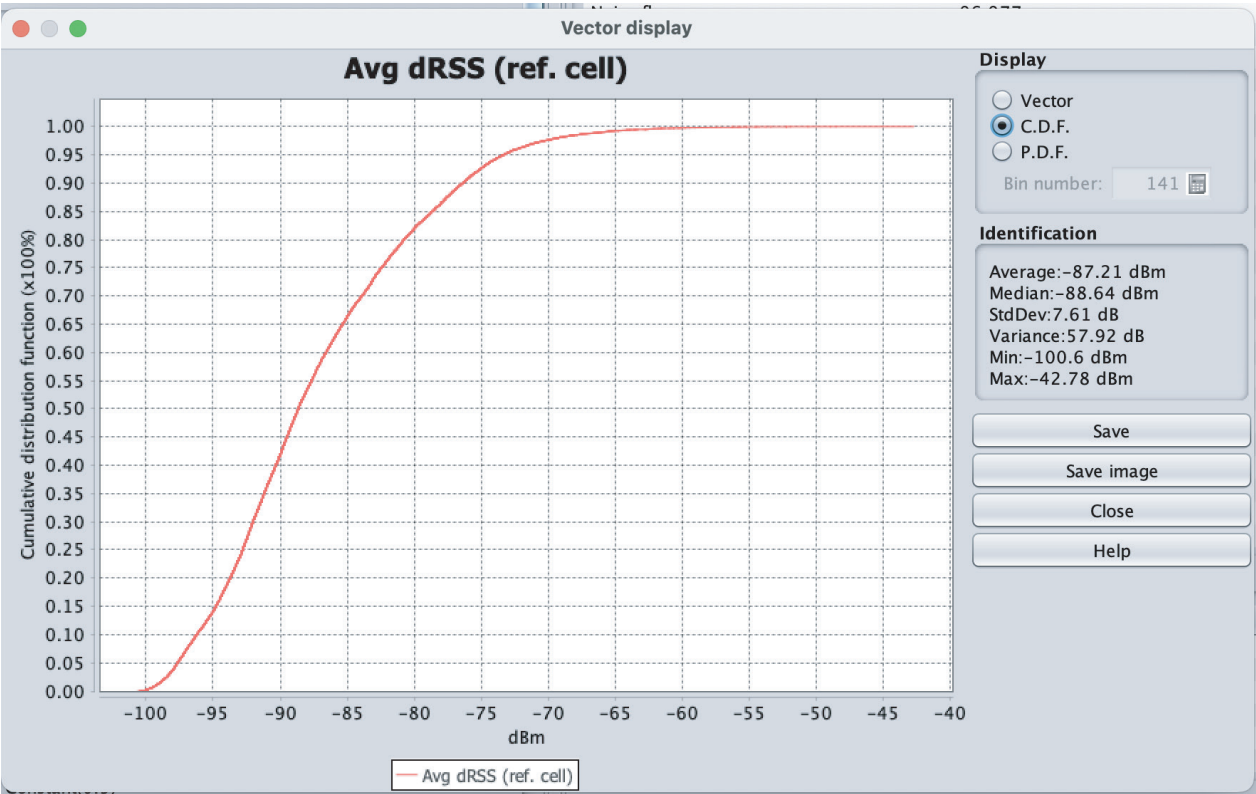


Figure 92: Zone-B-2, Kisamis Market Unmitigated Coexistence Scenario Network Layout

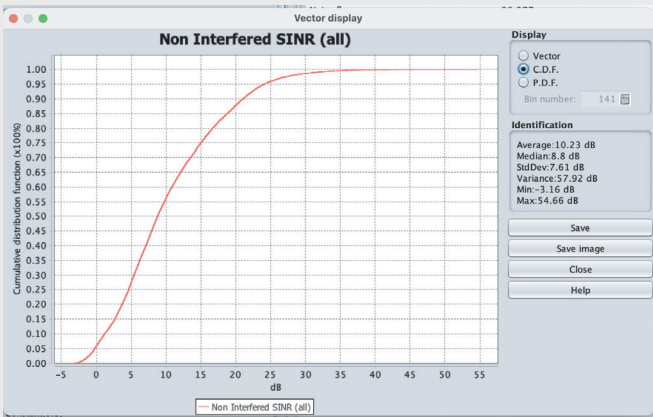
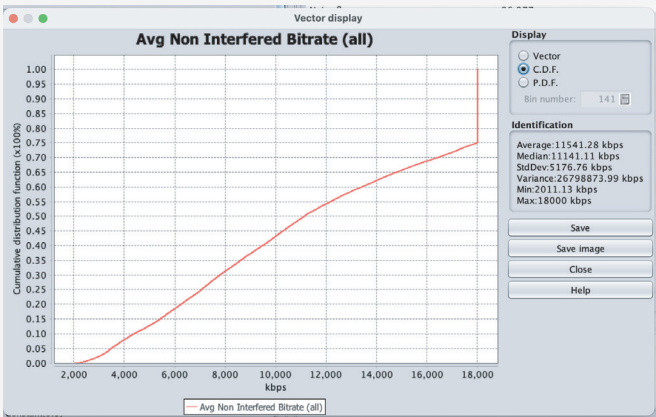
| Victim Results                | 3 NPNs ILT Link Results |
|-------------------------------|-------------------------|
| Average bitrate loss : 65.41% | Sub-carrier ratio 0.2   |
| Sub-carrier ratio 1.0         |                         |

In Zone B-2 when the three NPNs and the victim Safricom site are operational as shown the layout in Figure 90, the average bitrate loss in this scenario is 65.41%, which exceeds the desired maximum allowable degradation of 5% for Average Bitrate Loss in the LTE system. This indicates that the two systems are incompatible and cannot guarantee seamless coexistence in the reference cluster.

The average dRSS was -87.21 dBm, with maximum values of -42.78 dBm and minimum values of -100.6 dBm at the cell edge as the worst-case scenario as seen in Figure 91. Less than 5% of the simulated values were below the receiver's noise floor of -96.77 dBm. This indicates that the modelled victim cell has adequate reception without interference from the 3 NPN sites.



The Safaricom Victim system in Zone B-2–Kisamis Market achieved an average bitrate of 11.5 Mbps, see Figure 92. The minimum bitrate in the worst-case scenarios for this run was 2.0 Mbps. We observe that approximately 25% of the simultaneous events attain the maximum bitrate of 18 Mbps.



The link quality of the non-interfered victim system exhibits an average of 10.23 dB and a median SINR of 8.8 dB. At the extreme edge, the minimum SINR recorded is -3.16 dB, while the maximum recorded SINR is 54.66 dB. This is shown in Figure 93.



## Zone B-2- Kisamis Market Unmitigated Co-Existence Interference

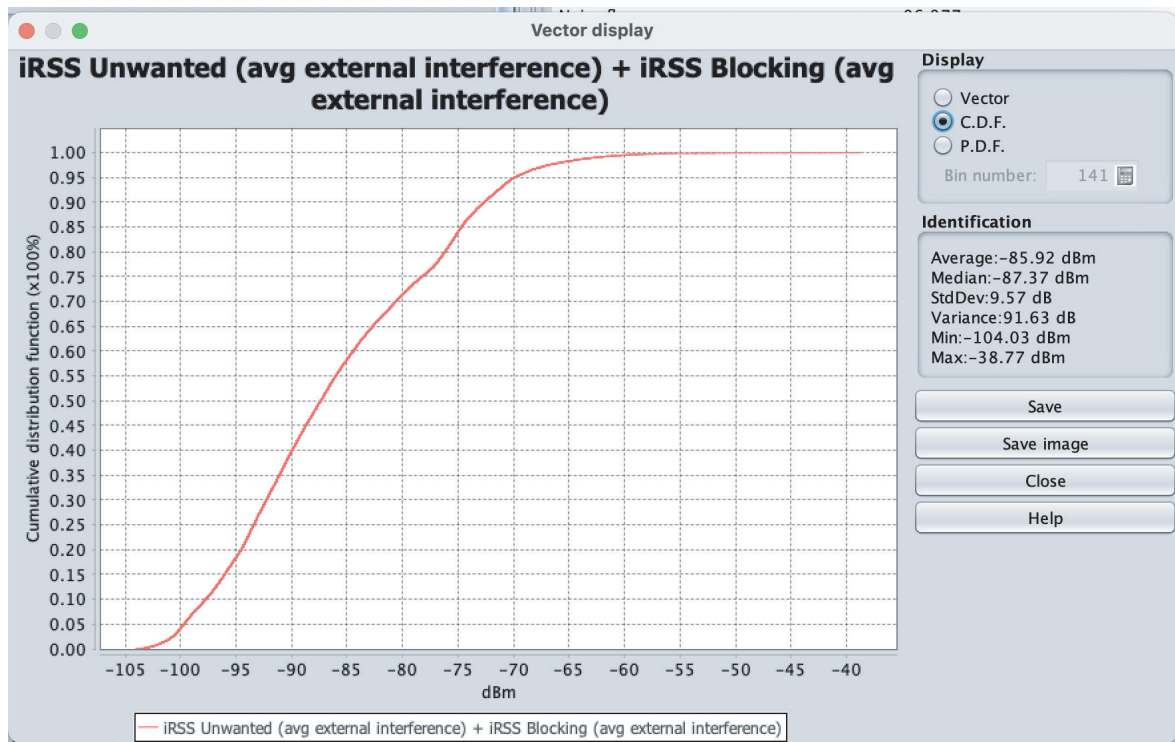


Figure 96: Zone B-2- Kisamis Market Corner: Unmitigated Co-Existence Interference iRSS Results

The average interfering Received Signal Strength (iRSS) leaking into the victim's receiver, and the median Unwanted Interference (iRSS) is -85.92 dBm and -87.37 dBm, respectively as seen in Figure 94. These values are almost equal to the average dRSS, which was -87.21 dBm in the non-interfered scenario. This indicates that the 3NPNs are almost overpowering the receivers served by the MNO site. The worst-case scenario is -104.57 dBm. In the interfering scenario, the ILT leaks into the victim's receiver with a signal strength of -38.77 dBm, which is slightly higher than the victim's maximum values of -42.78 dBm. This indicates severe interference from the 3 NPNs as ILT, causing performance degradation and an average bitrate loss of 65.41%.

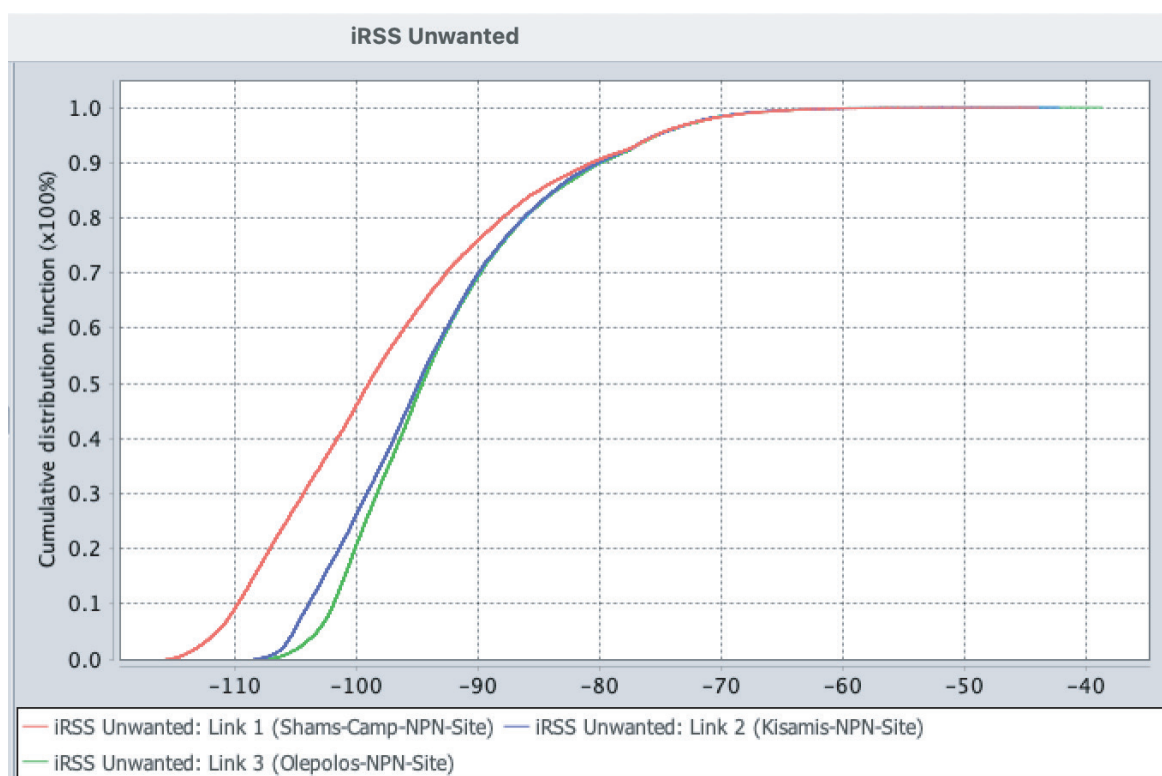


Figure 97: Zone B-2- Kisamis Market: Unmitigated Co-Existence Inference Individual iRSS Results from 3 NPN sites

In contrast, Figure 95 indicates that Olepolos and Kisamis NPNs sites are the most potent interferers, with 50% of their interfering signal iRSS instances being above -95 dBm. This observation is consistent with this study because Kisamis and Olepolos NPN are the closest NPN sites to the MNO's victim site, with a distance of only 2.340 and 2.724 kms to the VLT site.

Conversely, compared with the non-interfered SINR, the link quality of the interfered victim system deteriorates sharply. Figure 97 presents this. The average SINR drops from 10.23 dB to -2.32 dB, and the median SINR drops from 8.8 dB to -1.56 dB. This is a sharp decline and is indicative of the massive interference from the 3 NPN sites on the VLT. The worst-case scenario at the edge also shows drops in the Minimum SINR from -3.16 dB to -49.41 dB. The maximum recorded SINR also drops from 54.66 dB to 30.45dB. All these SINR figures indicate severe co-channel interference between the 3 NPN sites and Safaricom's VLT.

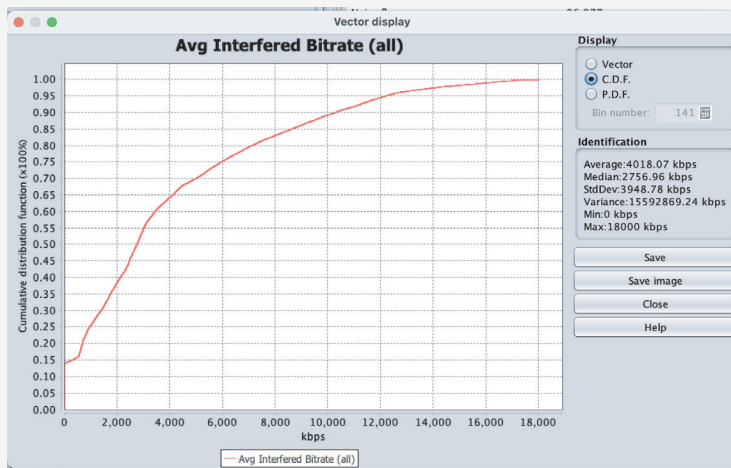


Figure 98: Zone B-2- Kisamis Market:  
Unmitigated Co-Existence Average Interfered Bitrate Results

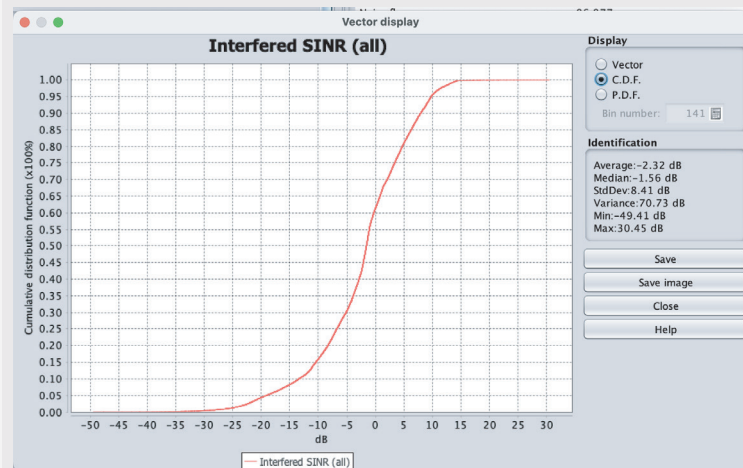


Figure 99: Zone B-2- Kisamis Market:  
Unmitigated Co-Existence Interfered SINR Results

When the system is interfered with by the 3 interfering links from the 3 NPNs at Olepolos, Shams Camp and Kisamis, the average bitrate drops to 4.01 Mbps with a higher standard deviation, see Figure 96. On the other hand, the worst-case scenario reports a bit rate of 0 kbps. This means that in the worst case, 15% of the receiver could exchange data with transmitter despite being connected due to interference from the 3 ILTs. Additionally, with interference from the 3 ILTs, less than 2% of the scenarios could attain the maximum bitrate during the transmission of 18 Mbps.

Zone B-2- Kisamis Market Interference Mitigation and Co-existence Optimisation

To mitigate against interference and facilitate coexistence, we modelled on SEAMCAT two scenarios: one where the Inter Site Distance between the 3 NPN sites and the Victim MNO Site is 15 kilometres, and the other where Multi-Channel Transmission occurs between the NPN and the VLT MNO sites. We present these mitigation results in the subsequent section.

Strategy 1: Inter-site distance of 15KM between the 3 NPN sites and the Victim MNO Site

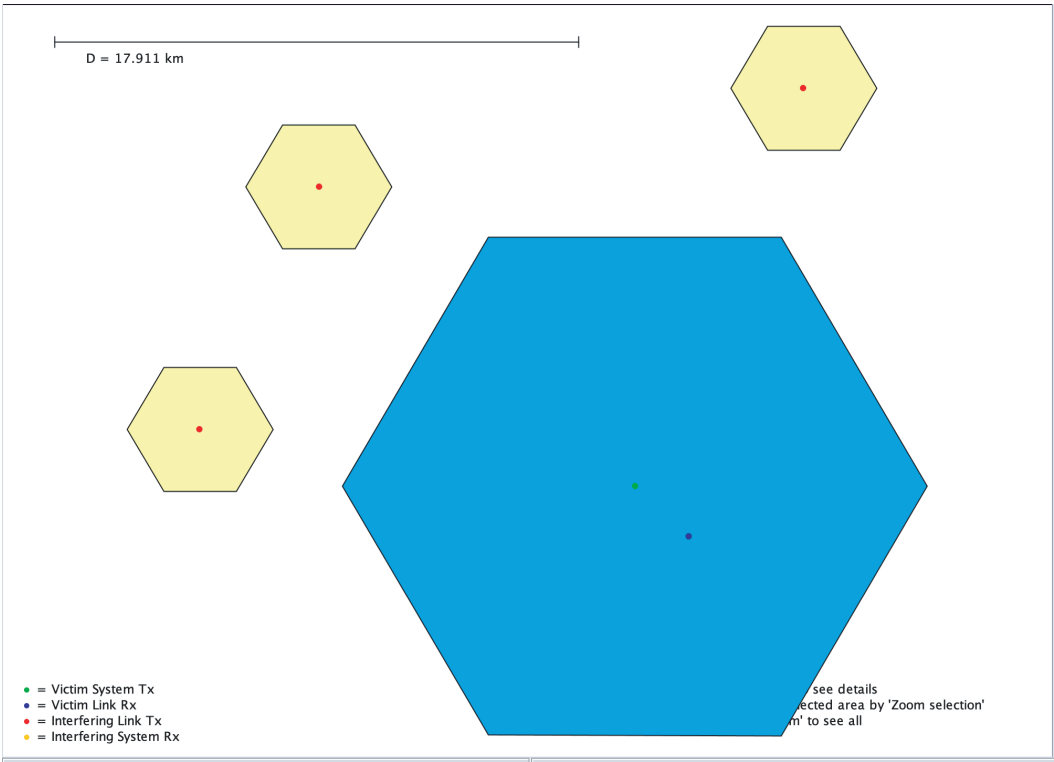


Figure 100: Zone B-2- Kisamis Market Strategy 1 Mitigation Coexistence Scenario Network Layout

| Victim Results                 | 3 NPNs ILT Link Results |
|--------------------------------|-------------------------|
| Average bitrate loss : 14.973% | Sub-carrier ratio 0.2   |
| Sub-carrier ratio 1.0          |                         |

After considering the Inter Site Distance of 15 kilometres between the 3 NPN sites and the Victim MNO site, as shown in Figure 98, the Average bitrate loss decreases to 14.973% as seen in Table 31. This value is still higher than the maximum allowable degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system of 5%. Consequently, the two systems are clusters are not compatible and cannot guarantee seamless coexistence within the reference cluster. Other coexistence mechanisms need to be considered.



## Zone B-2- Kisamis Market: Mitigation Strategy 1 Co-Existence Average dRSS, Average Non-Interfered Bitrate and Non-Interfered SINR results

After considering the Inter Site Distance of 15KM between the 3 NPN sites and the Victim MNO site, the average dRSS remains relatively unchanged compared to the scenario where interference mitigation and coexistence optimisation are not taken into account. In fact, the average non-interfered bitrate and the non-interfered SINR in this scenario are not significantly different from the baseline coexistence study discussed earlier, prior to interference mitigation and coexistence optimisation. This is shown in Figures 99, 100 and 101.

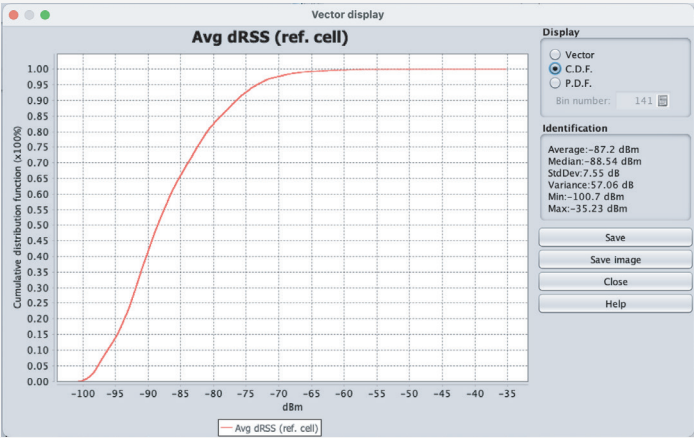


Figure 101: Zone B-2- Kisamis Market:  
Mitigation Strategy 1 Co-Existence Average dRSS results

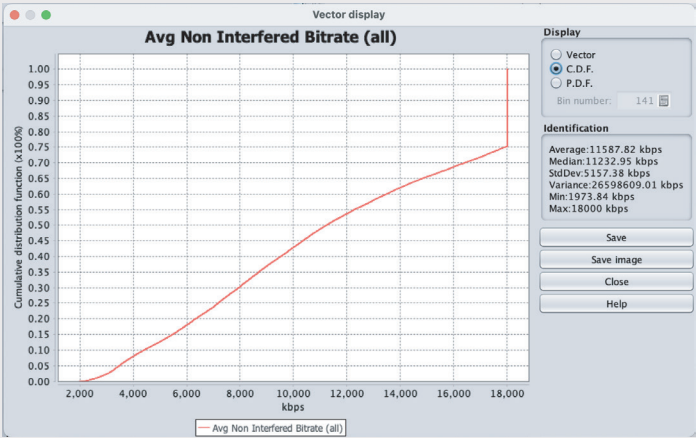


Figure 102: Zone B-2- Kisamis Market:  
Mitigation Strategy 1 Co-Existence Average Non-Interfered Bitrate results

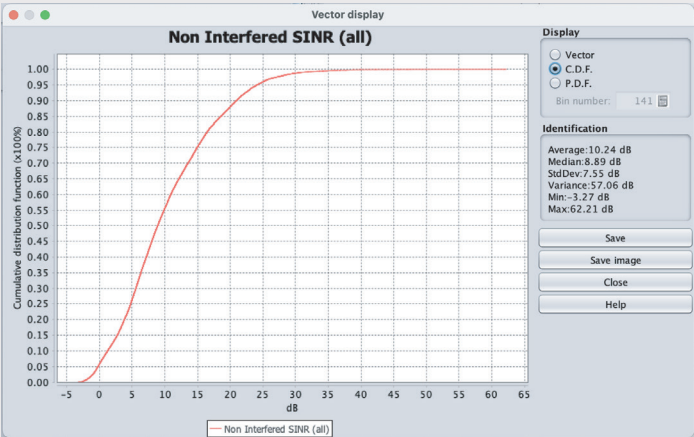


Figure 103: Zone B-2- Kisamis Market:  
Mitigation Strategy 1 Co-Existence Non Interfered SINR

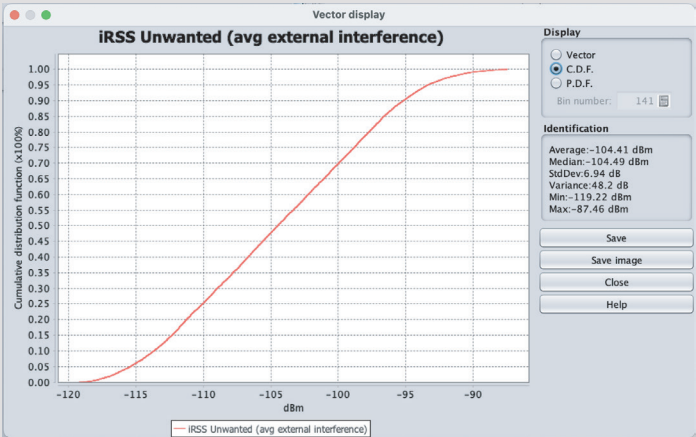


Figure 104: Zone B-2- Kisamis Market:  
Mitigate Strategy 1 Co-Existence Interference iRSS results

After considering the Inter Site Distance of 15 kilometres between the 3 NPN sites and the Victim MNO site, the interfering Received Signal Strength significantly decreases from -85.92 dBm to -104.41 and the median Unwanted Interference (iRSS) also decreases from -87.37 dBm to -104.49. The worst-case scenario also decreases from -98.07 dBm in the non-interference case to -104.57 dBm to -119.22 dBm. All these improvements as seen in Figure 102 indicate an improved link with minimal interference from the ILT. However, these improvements are not enough to ensure that the minimal interference and falls within the permissible degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system, which is 5% average bitrate loss.

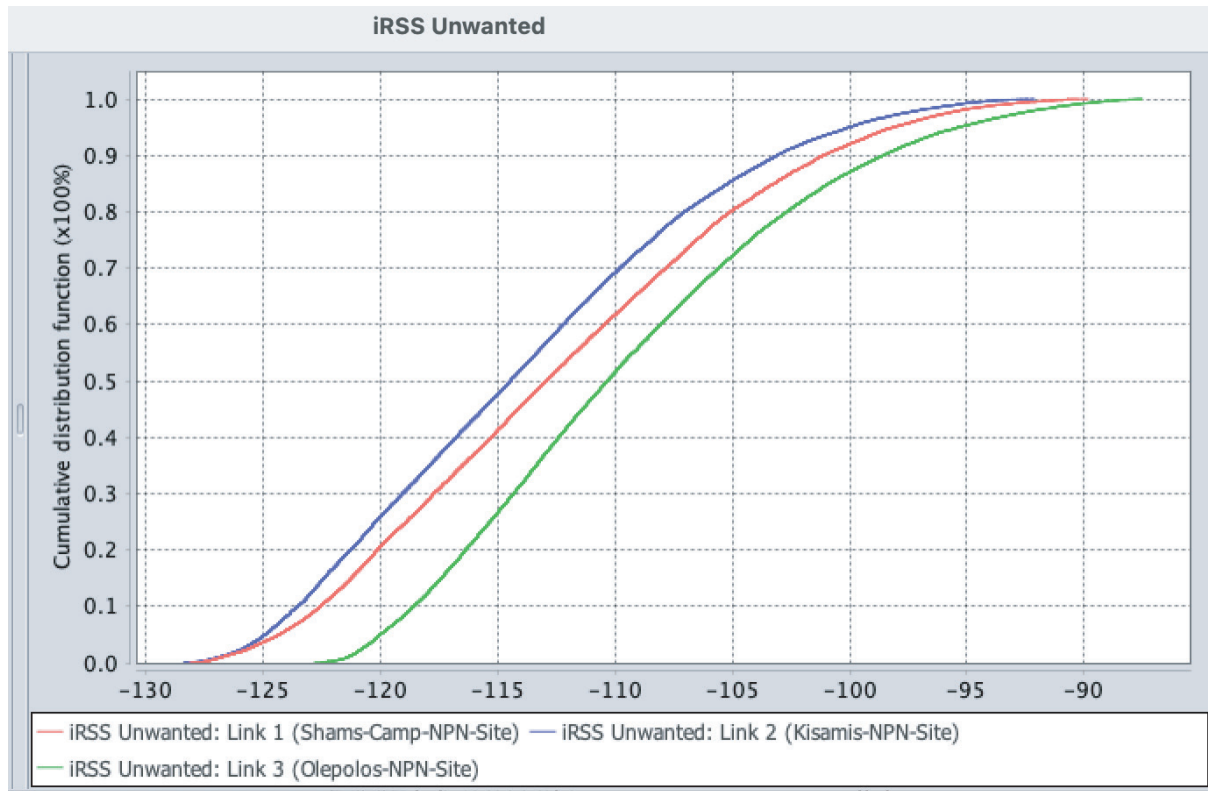


Figure 105: Zone B-2- Kisamis Market: Mitigation Strategy 1 Co-Existence Interference Individual iRSS Results from 3 NPN

In contrast, Figure 103 indicates that Olepolos NPN site is the most potent interferer, with close to 95% of its interfering signal iRSS instances being above -95 dBm. This observation is consistent with this study because with the mitigation strategy of increasing the inter-site distance to 15 km between the 3 NPN sites and the Victim MNO site, Olepolos NPN site ended up being the closest NPN site to the MNO's victim site, as shown in Figure 86.

When considering the Inter Site Distance of 15KM between the 3 NPN sites and the Victim MNO site, the average bitrate also indicates an improved link. This value increases from 4.01 Mbps to 10.2 Mbps. Additionally, as seen in Figure 104, from the simulation runs, after considering the Inter-Site Distance of 15KM between the 3 NPN sites and the Victim MNO site, more than 23% of the scenarios could attain the maximum bitrate during transmission of 18Mbps. This represents an improvement from the 2% achieved in the interfered link without any Interference Mitigation or Co-existence Optimisation strategies implemented.

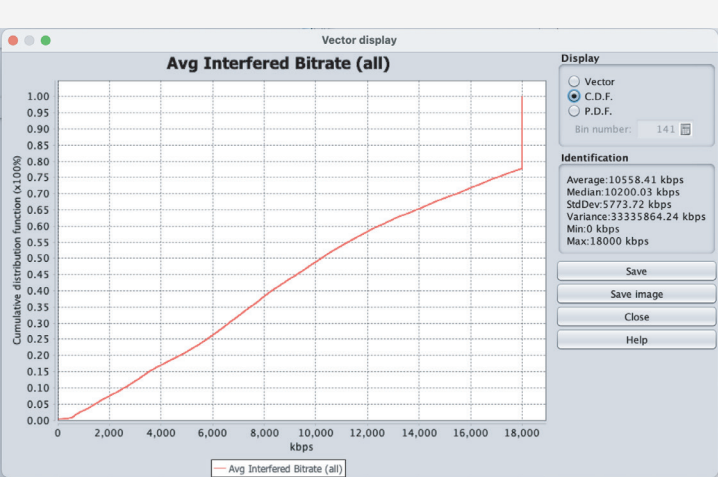


Figure 106: Zone B-2- Kisamis Market:  
Mitigation Strategy 1 Co-Existence Interference Average Bitrate results

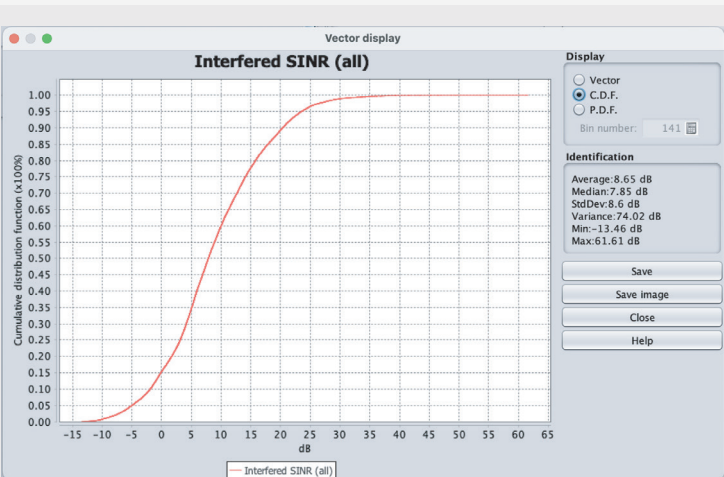


Figure 107: Zone B-2- Kisamis Market:  
Mitigate Strategy 1 Co-Existence Interference Interfered SINR results

The interfered SINR improves significantly when considering an Inter-Site Distance of 15 km between the NPN site and the Victim MNO site, as seen in Figure 105. The previous average SINR of 1.56 dB increases to 8.65 dB, while the median SINR rises from -1.56 dB dB to 7.85 dB. Even at the edge of the cell, the worst-case scenario shows a remarkable improvement in SINR from -49.41 dB to -13.46 dB. These enhanced SINR values indicate that the link improved post Interference Mitigation and Co-existence Optimisation strategies have been successfully implemented. However, the two systems are still not compatible and cannot guarantee seamless coexistence within the reference cluster, given the current conditions.



## Strategy 2: Multi-Channel Transmission between NPN and VLT MNO

The second Interference Mitigation and Coexistence Optimisation strategy employed Multi-Channel Transmission between NPN and VLT MNO. This strategy retained the original inter-site distances for all 3 NPN sites. However, the 3 NPNs were transmitting at centre frequencies of 1825 MHz. Additionally, we expanded the MNOs receiver blocking response upper limit to  $\pm 30$  MHz at 50 dB and the 3 NPN ILT transmitters' out-of-band emission limits to  $\pm 35$  MHz at -65 dB to ensure experiment fidelity. The outcomes are as follows.

| Victim Results               | 3 NPNs ILT Link Results |
|------------------------------|-------------------------|
| Average bitrate loss: 0.416% | Sub-carrier ratio 0.2   |
| Sub-carrier ratio 1.0        |                         |

Table 26: Zone B-2- Kisamis Market: Mitigate Strategy 2 Co-Existence Results

After considering Multi-Channel Transmission between the 3 NPNs and VLT MNO, the Average bitrate loss decreases to 0.416%. This, as shown in Table 32, represents minimal interference and falls within the permissible degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system. Consequently, the two systems are compatible and can ensure seamless coexistence within the reference cluster.

### Zone B-2- Kisamis Market: Mitigation Strategy 2 Co-Existence Average dRSS, Average Non-Interfered Bitrate and Non-Interfered SINR results

After considering Multi-Channel Transmission between the 3 NPNs and the VLT MNO, the average dRSS remains relatively unchanged compared to the scenario in which interference mitigation and Co-existence Optimisation are not taken into account. Similarly, the average Non-Interfered bitrate and the non-interfered SINR in this scenario are not significantly different from those in the baseline coexistence study discussed earlier, before considering interference mitigation and Co-existence Optimisation. Figures 106, 107 and 108 show this.

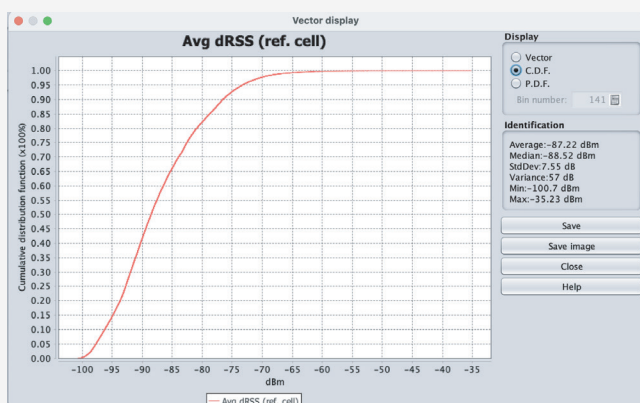


Figure 108: Zone B-2- Kisamis Market: Mitigation Strategy 2 Co-Existence Average dRSS

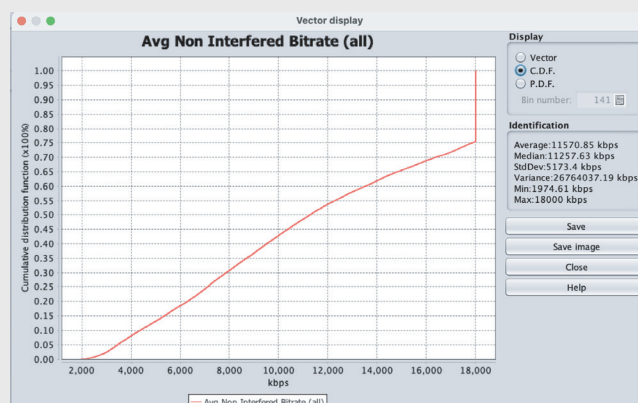


Figure 109: Zone B-2- Kisamis Market: Mitigation Strategy 2 Co-Existence Average Non-Interfered Bitrate

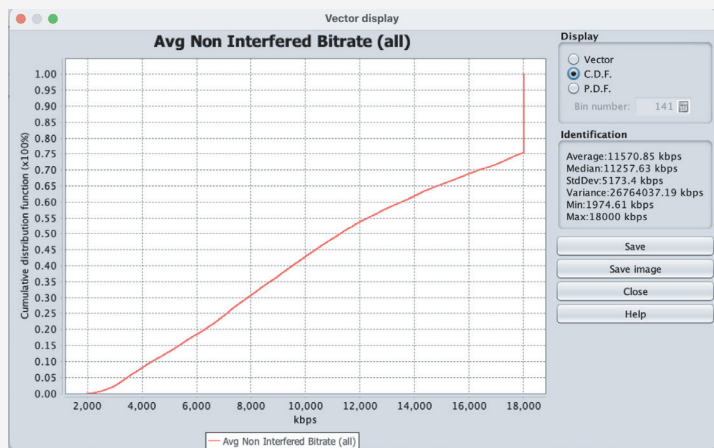


Figure 109: Zone B-2- Kisamis Market:  
Mitigation Strategy 2 Co-Existence Average Non-Interfered Bitrate

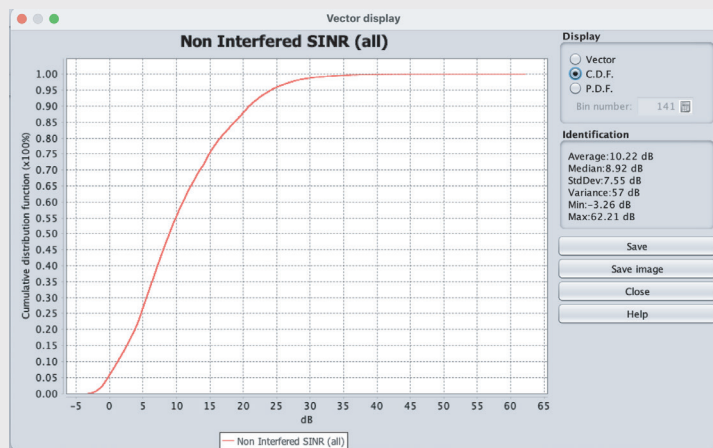


Figure 110: Zone B-2- Kisamis Market:  
Mitigation Strategy 2 Co-Existence Non-Interfered SINR results

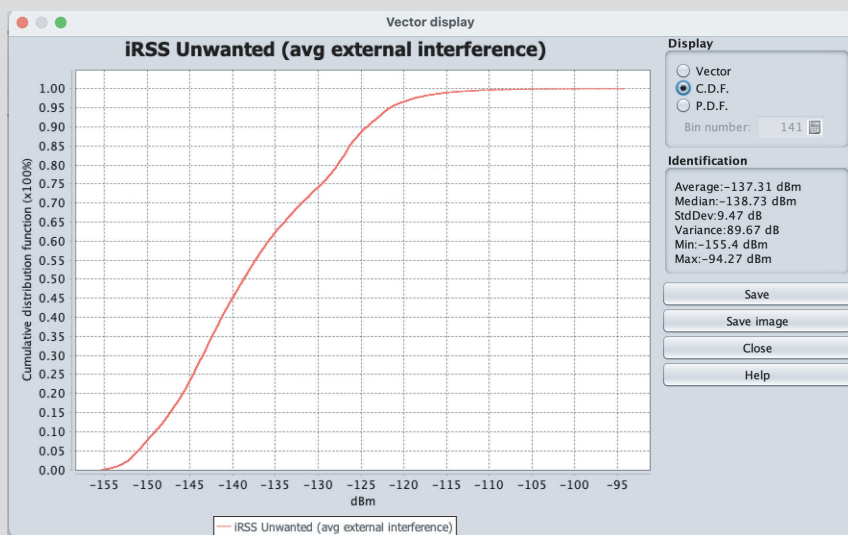


Figure 111: Zone B-2- Kisamis Market:  
Mitigation Strategy 2 Co-Existence Interference iRSS results

In contrast, when considering Multi-Channel Transmission between the 3 NPNs and the VLT MNO, the interfering Received Signal Strength further decreases from -104.41 dBm at an intersite distance of 15 km to -137.31 dBm. This represents an even more significant improvement. The median Unwanted Interference (iRSS) also drops from -104.49 dBm to -138.73 dBm. The worst-case scenario also decreases further from -119.22 dBm to -155.4 dBm. All these improvements, captured in Figure 109, indicate an enhanced link with minimal interference from the ILT when Multi-Channel Transmission between NPN and VLT MNO is considered.

In contrast, Figure 110 indicates that that Olepolos and Kisamis NPNs sites are the most potent interferer, nonetheless. This observation is consistent with this study because Kisamis and Olepolos NPN sites are the closest NPN site to the MNO's victim site, with a distance of only with a distance of only 2.340 Kms and 2.724 Kms to the VLT site respectively. Only this time the Multi-Channel Transmission between NPN and VLT MNO is considered as an interference mitigation and coexistence strategy.

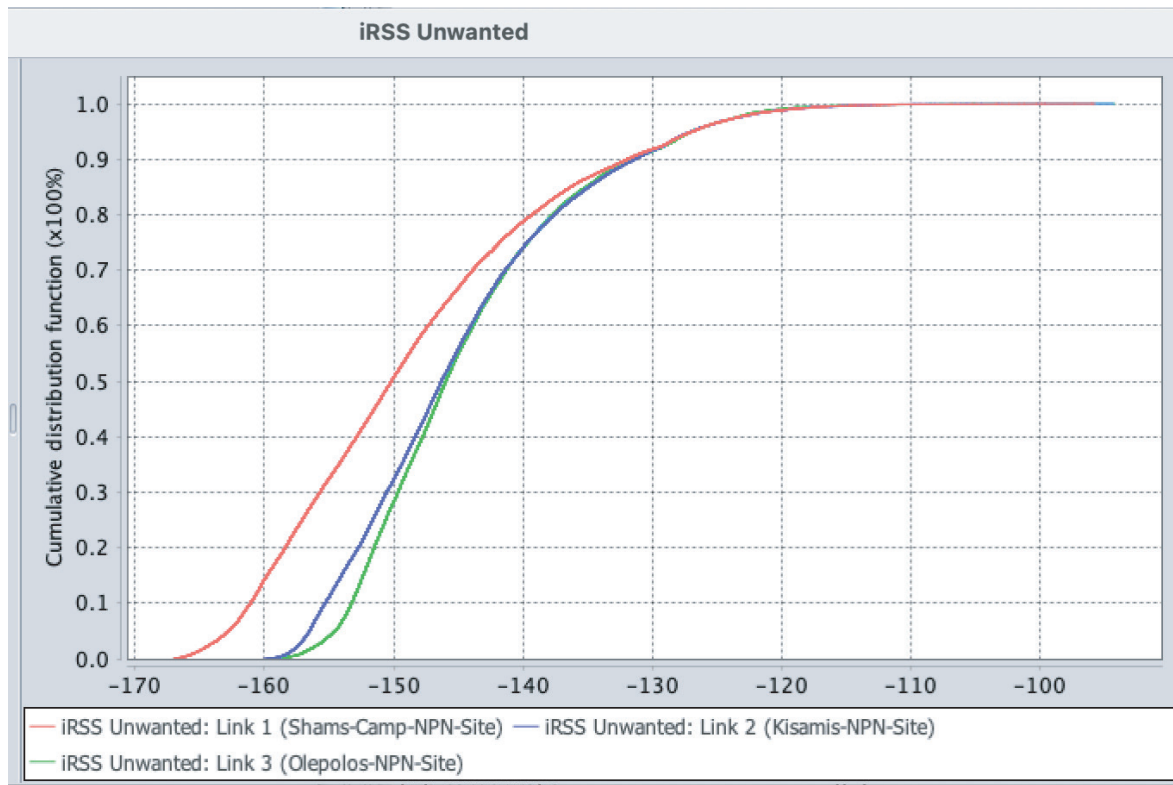


Figure 112: Zone B-2- Kisamis Market: Mitigation Strategy 2 Co-Existence Interference Individual iRSS Results from 3 NPN

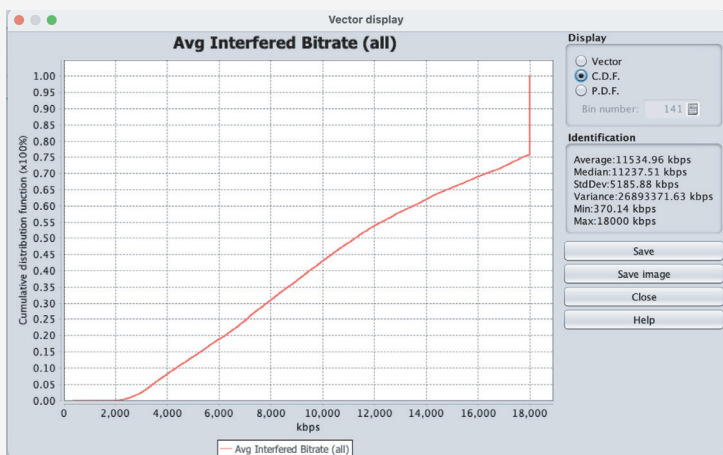


Figure 113: Zone B-2- Kisamis Market: Mitigation Strategy 2 Co-Existence Interference Average Bitrate results

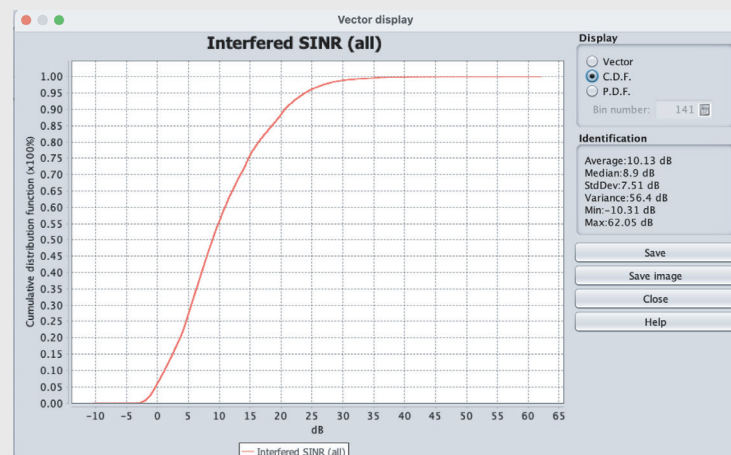


Figure 114: Zone B-2- Kisamis Market: Mitigation Strategy 2 Co-Existence Interference Interfered SINR results

When considering Multi-Channel Transmission between the 3 NPNs and the VLT MNO, the average bitrate indicates an improved link, as shown in Figure 111. This value increases from 10.2 Mbps when the Inter Site Distance between the NPN site and Victim MNO Site is 15KM to 11.5 Mbps. Furthermore, more than 23% of the scenarios can achieve the maximum bitrate of 18 Mbps during transmission. Conversely, fewer than 1% of scenarios transmit at a minimum rate of 370 Kbps. In general, the coexistence strategy for Multi-Channel Transmission between the 3 NPN and VLT MNO improves the average bitrate.



The interfered SINR Multi-Channel Transmission between the 3 NPNs and VLT MNO also improves, see Figure 112. The previous average SINR of 8.65 dB has increased to 10.13 dB. The median SINR has also increased from 7.85 dB to 8.9 dB. These improvements indicate that the link post-interference mitigation and coexistence optimisation strategies have been successfully implemented. The two systems are now compatible and can guarantee seamless coexistence in the reference cluster.

## Zone C Oltepesi Tinga Co-existence Study

| Parameters                            | Safaricom Site 127 LTE (VLT) | Tinga NPN Site (ILT) |
|---------------------------------------|------------------------------|----------------------|
| Power                                 | 3W                           | 1W                   |
| Frequency                             | 1800 MHZ                     | 1800 MHZ             |
| TX Gain                               | 18.44 dBi                    | 3.5dBi               |
| EIRP                                  | 186.6901W                    | 2.238721W            |
| losses                                | 0.5db                        | 0                    |
| Antenna Height                        | 34.2m                        | 20m                  |
| TX/RX Bandwidth                       | 10MHZ                        | 10MHz                |
| Propagation Model                     | ITU-R-P452-18                | ITU-R-P452-18        |
| Technology                            | LTE FDD                      | LTE FDD              |
| Sub Carrier Spacing                   | 15KHz                        | 15KHz                |
| Total RBs                             | 50                           | 50                   |
| Total Subcarriers                     | 600                          | 600                  |
| RB bandwidth                          | 180KHz                       | 180KHz               |
| RX noise figure                       | 7 dB                         | 7 dB                 |
| Minimum Coupling loss                 | 70 dB                        | 70 dB                |
| Handover Margin                       | 1.5 dB                       | 1.5 dB               |
| Standard Disensitization              | 6 dB                         | 6 dB                 |
| Target I/N                            | -6 dB                        | -6 dB                |
| Antenna Radiation                     | Isotropic                    | Isotropic            |
| Antenna Pattern TX                    | ITU-R F.1336                 | ITU-R F.1336         |
| Antenna Arrays TX/RX                  | 1/1                          | 1/1                  |
| Antenna Tilt                          | 0                            | 0                    |
| Activity Uplink                       | 100%                         | 100%                 |
| Activity Downlink                     | 100%                         | 100%                 |
| TX Clutter                            | Open-Rural                   | Open-Rural           |
| RX Clutter                            | Open-Rural                   | Open-Rural           |
| Relative Distance to VTL              | NA                           | 2.5457km             |
| Path Azimuth Relative to ILT from VLT | NA                           | 8.13                 |

In Zone-C, Oltepesi Tinga Safaricom LTE Site 127 is the victim, while Tinga NPN Site is the interferer. The network layout shown in Figure 113 represents this scenario, based on the coexistence parameters outlined in the preceding table.

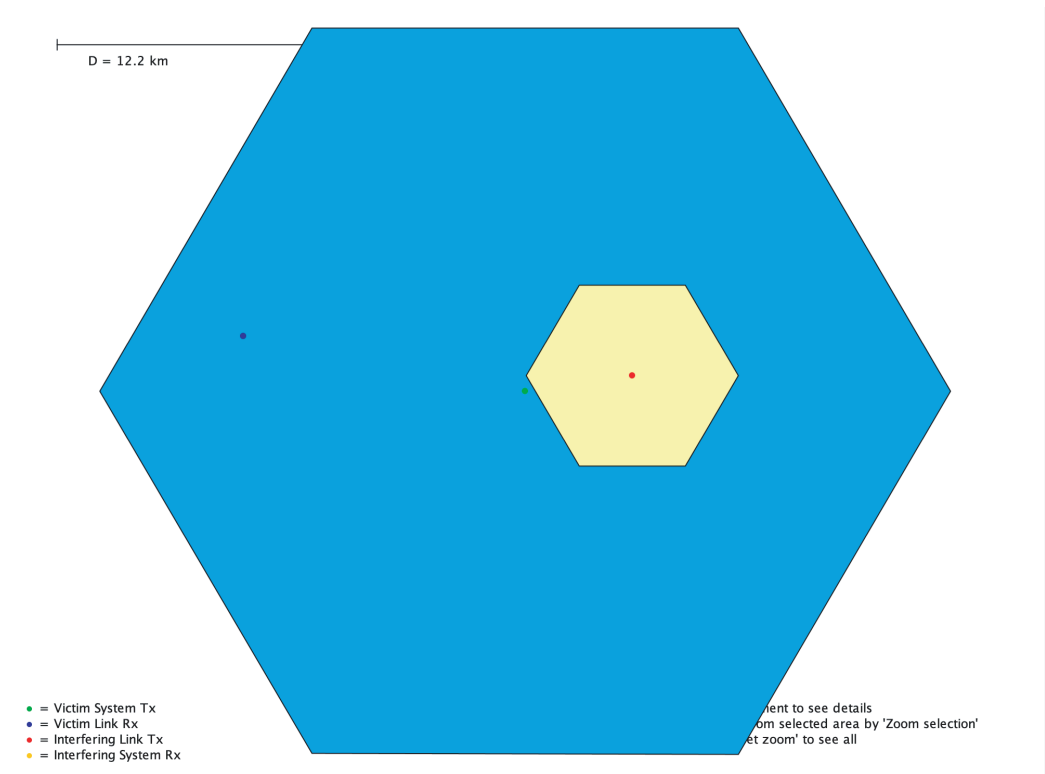


Figure 115: Zone C Oltepesi Tings Unmitigated Coexistence Scenario Network Layout

| Victim Results                | 3 NPNs ILT Link Results |
|-------------------------------|-------------------------|
| Average bitrate loss : 39.35% | Sub-carrier ratio 0.2   |
| Sub-carrier ratio 1.0         |                         |

Table 28: Zone C Oltepesi Tinga Unmitigated Co-Existence Baseline Results

The average bitrate loss in this scenario as presented in Table 34 is 39.35%, which exceeds the desired maximum allowable degradation of 5% for Average Bitrate Loss in the LTE system. This indicates that the two systems are incompatible and cannot guarantee seamless coexistence in the reference cluster.

The average dRSS was -88.55 dBm, with maximum values of -44.59 dBm and minimum values of -101.95 dBm at the cell edge as the worst-case scenario, see Figure 114. Less than 5% of the simulated values were below the receiver's noise floor of -96.77 dBm. This indicates that the modelled victim cell has adequate reception without interference from the NPN site.

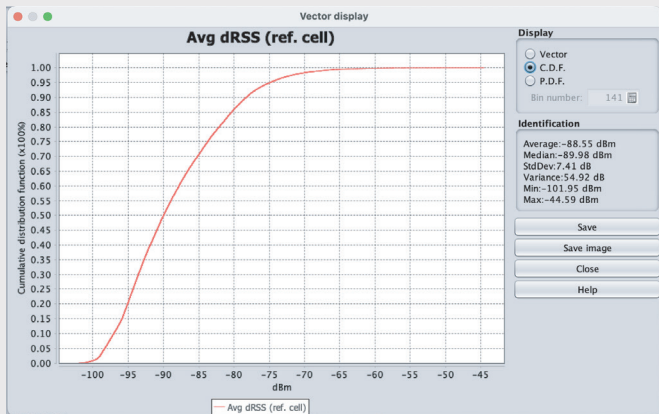


Figure 116: Zone C- Oltepesi Tinga:  
Unmitigated Co-Existence Average dRSS Results

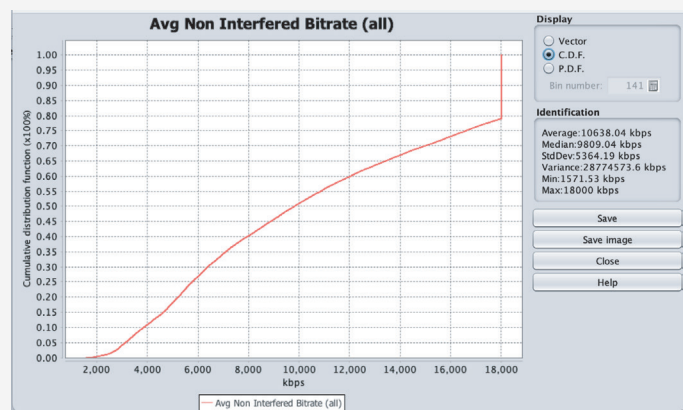


Figure 117: Zone C- Oltepesi Tinga:  
Unmitigated Co-Existence Average Non Interfered Bitrate Results

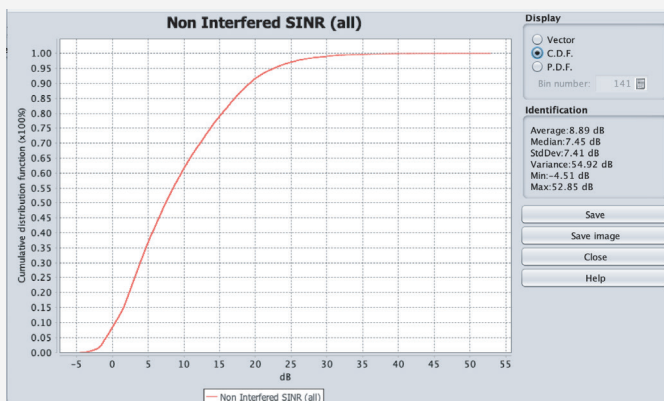


Figure 118: Zone C- Oltepesi Tinga:  
Unmitigated Co-Existence Average Non-Interfered SINR Results

The Safaricom Victim system in Zone C- Oltepesi Tinga achieved an average bitrate of 10.6 Mbps as seen in Figure 115. The minimum bitrate in the worst-case scenarios for this run was 1.57 Mbps. We observe that approximately 23% of the simultaneous events attain the maximum bitrate of 18 Mbps.

The link quality of the non-interfered victim system exhibits an average of 8.89 dB and a median SINR of 7.45 dB. At the extreme edge, the minimum SINR recorded is -4.51 dB, while the maximum recorded SINR is 52.85 dB, see Figure 116.

# Zone C Oltepesi Tinga Unmitigated Co-Existence Interference

This interfering Received Signal Strength (iRSS) is signal leakage into the victim's receiver. The average Unwanted Interference (iRSS) is -93.19 dBm, which is still closer to the desired average dRSS -88.55 dBm. On the other hand, the median Unwanted Interference (iRSS) is -95.48 dBm, which is also closer to the desired median dRSS (-89.98 dBm). This indicates that the NPN site is almost overpowering the receivers served by the MNO site. The worst-case scenario is -108.87 dBm. In the interfering scenario, the ILT leaks into the victim's receiver with a signal strength of -48.57 dBm, which is closer to the victim's maximum values of -44.59dBm. These values in Figure 117 indicate severe interference from the NPN site as the ILT, causing performance degradation and an average bitrate loss of 39.35% seen in Table 34.

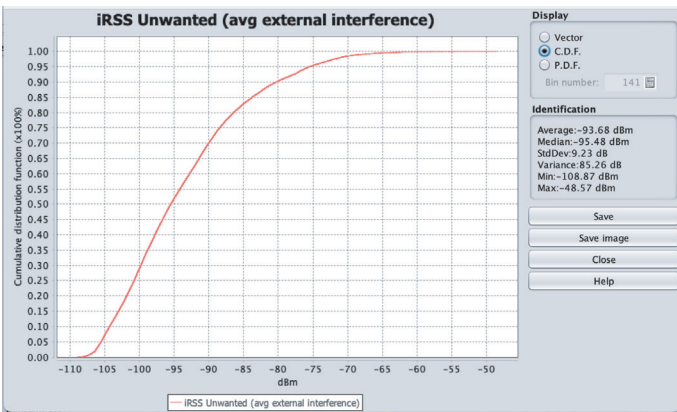


Figure 119: Zone C Oltepesi Tinga:  
Unmitigated Co-Existence Interference iRSS Results

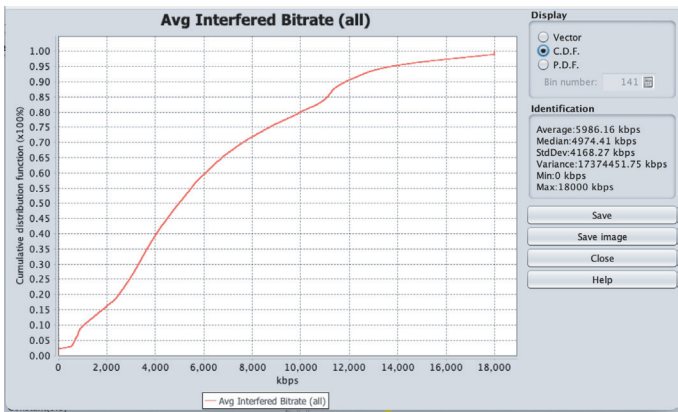


Figure 120: Zone C Oltepesi Tinga:  
Unmitigated Co-Existence Average Interfered Bitrate Results

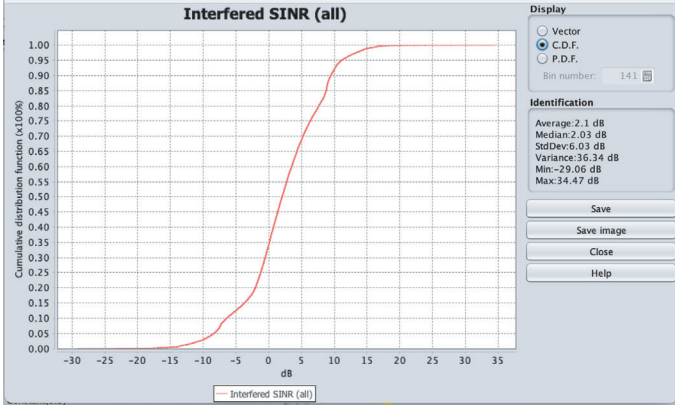


Figure 121: Zone C Oltepesi Tinga:  
Unmitigated Co-Existence Interfered SINR Results

When the system is interfered with by an interfering link from the NPNs at Tinga, the average bitrate drops to 5.98 Mbps with a higher standard deviation as shown in Figure 118. On the other hand, the worst-case scenario reports a bitrate of 0 kbps. This means that in the worst case, 3% of the receiver could not exchange data with transmitter despite being connected due to interference from the 3 ILTs. Additionally, with interference from the ILT, less than 5% of the scenarios could attain the maximum bitrate during the transmission of 18 Mbps.



When compared with the non-interfered SINR, the link quality of the interfered victim system deteriorates sharply. The average SINR drops from 8.89 dB to 2.1 dB, and the median SNIR drops from 7.45 dB to 2.03 dB. This is a sharp decline as represented in Figure 119 and is indicative of the massive interference from the Tinga NPN site on the VLT. The worst-case scenario at the edge also shows drops in the Minimum SINR from -4.51 dB to -29.06 dB. The maximum recorded SINR also drops from 52.85 dB to 34.47dB. All these SINR figures indicate severe co-channel interference between the NPN site in Tinga and Safaricom’s VLT.

### Zone C Oltepesi Tinga Interference Mitigation & Co-existence Optimisation

To mitigate against interference and facilitate coexistence, we modelled on SEAMCAT two scenarios: one where the Inter Site Distance between the NPN site in Tinga and the Victim MNO Site is 15 kilometres, and the other where Multi-Channel Transmission occurs between the NPN and the VLT MNO sites. We present these mitigation results in the subsequent section.

Strategy 1: Inter Site Distance of 15KM between the NPN site and Victim MNO Site

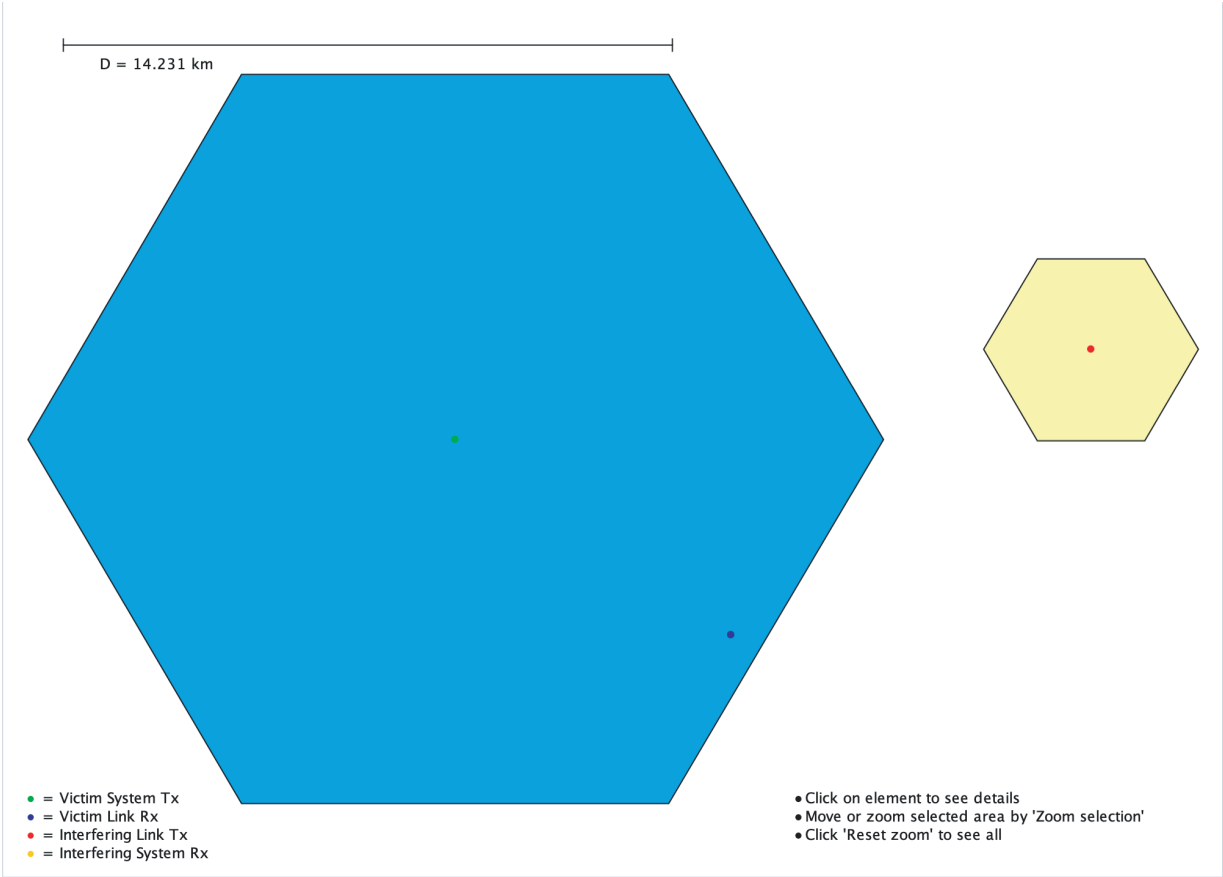


Figure 122: Zone C Oltepesi Tinga Strategy 1 Mitigation Coexistence Scenario Network Layout

| Victim Results                | NPN ILT Link Results  |
|-------------------------------|-----------------------|
| Average bitrate loss : 3.927% | Sub-carrier ratio 0.2 |
| Sub-carrier ratio 1.0         |                       |

Table 29: Zone C Oltepesi Tinga Strategy 1 Mitigation Coexistence Results

After considering the Inter Site Distance of 15 kilometres between the NPN site in Tinga and the Victim MNO site, as shown in Figure 120, the Average bitrate loss decreases to 3.927%, see Table 35. This represents minimal interference and falls within the permissible degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system. Consequently, the two systems are compatible and can ensure seamless coexistence within the reference cluster

## Zone C Oltepesi Tinga: Mitigation Strategy 1 Co-Existence Average dRSS, Average Non-Interfered Bitrate and Non-Interfered SINR results

After considering the Inter Site Distance of 15KM between the NPN sitesat Tinga and the Victim MNO site, the average dRSS remains relatively unchanged compared to the scenario where interference mitigation and coexistence optimisation are not taken into account. In fact, the average non-interfered bitrate and the non-interfered SINR in this scenario are not significantly different from the baseline coexistence study discussed earlier, prior to interference mitigation and coexistence optimisation. We show this Figures 121, 122, 123.

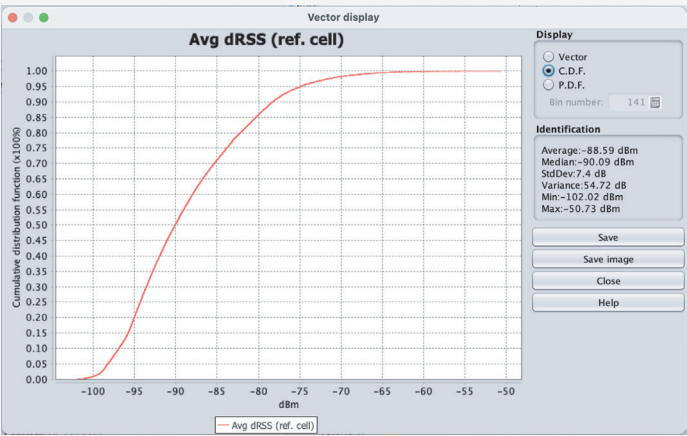


Figure 123: Zone C Oltepesi Tinga: Mitigation Strategy 1 Co-Existence Average dRSS results

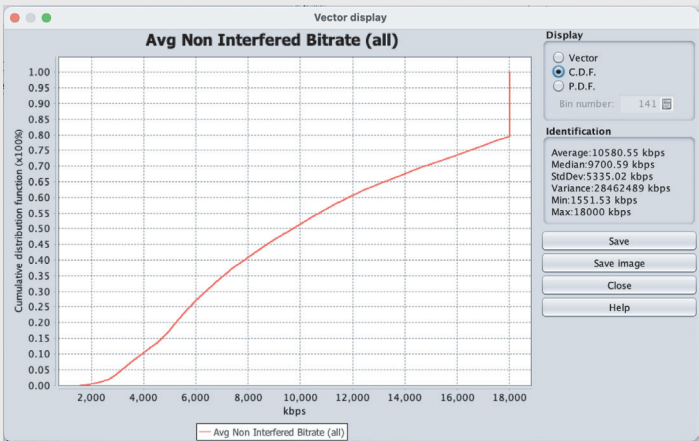


Figure 124: Zone C Oltepesi Tinga: Mitigation Strategy 1 Co-Existence Average Non Interfered Bitrate results

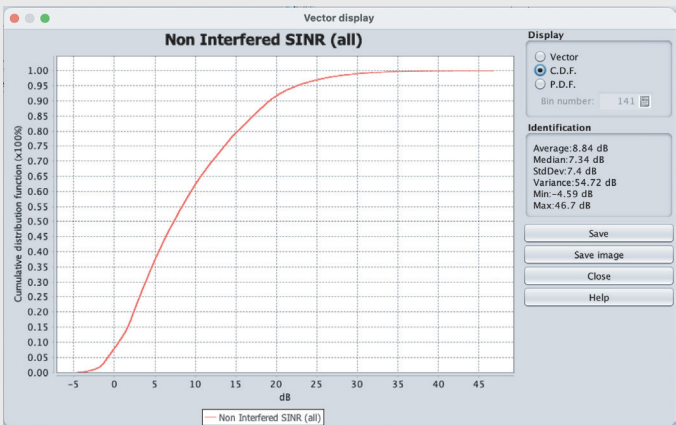


Figure 125: Zone C Oltepesi Tinga: Mitigation Strategy 1 Co-Existence Non Interfered SINR

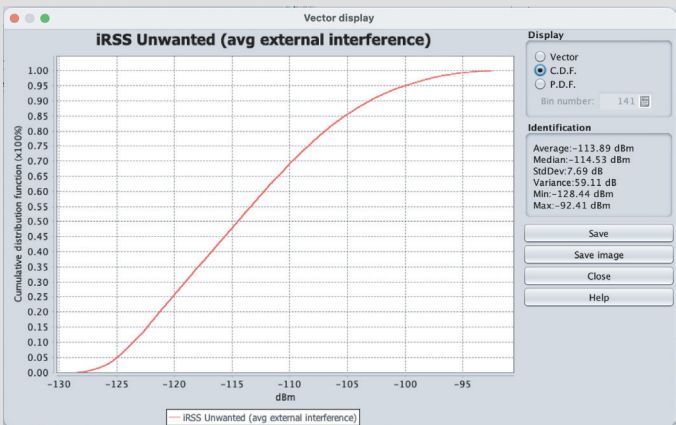


Figure 126: Figure 112: Zone C Oltepesi Tinga: Mitigate Strategy 1 Co-Existence Interference iRSS

After considering the Inter Site Distance of 15 kilometres between the NPN site at Tinga and the Victim MNO site, the interfering Received Signal Strength significantly decreases from -93.19 dBm to -113.89 and the median Unwanted Interference (iRSS) also decreases from -89.98 dBm to -114.53 as seen in Figure 124. The worst-case scenario also decreases from -98.07 dBm in the non-interference case to -108.87 dBm to -128.44 dBm. All these improvements indicate an improved link with minimal interference from the ILT. However, these improvements are enough to ensure that the minimal interference and falls within the permissible degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system, which is 5% average bitrate loss.

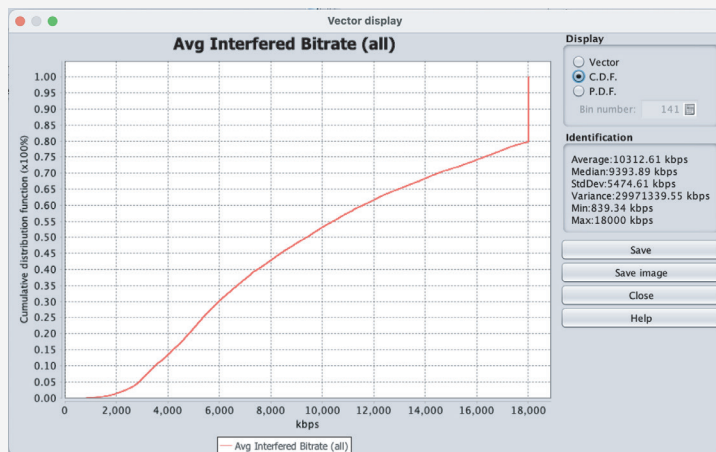


Figure 127: Zone C Oltepesi Tinga:  
Mitigation Strategy 1 Co-Existence Interference Average Bitrate results

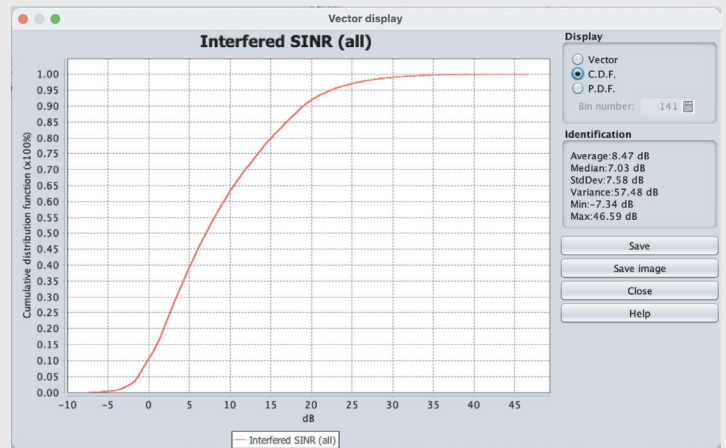


Figure 128: Zone C Oltepesi Tinga:  
Mitigation Strategy 1 Co-Existence Interference Interfered SINR results

When considering the Inter Site Distance of 15KM between the NPN sites at Tinga the Victim MNO site, the average bitrate also indicates an improved link. This value increases from 5.98 Mbps to 10.3 Mbps. Additionally, from the simulation runs, after considering the Inter Site Distance of 15KM between the NPN at Tinga and the Victim MNO site, more than 25% of the scenarios could attain the maximum bitrate during transmission of 18Mbps. This represents an improvement from the 5% achieved in the interfered link without any Interference Mitigation or Co-existence Optimisation strategies implemented. We show this in Figure 125.

The interfered SINR improves significantly when considering an Inter Site Distance of 15 km between the NPN site and the Victim MNO site. The previous average SINR of 2.1 dB increases to 8.47 dB, while the median SINR rises from 2.03 dB to 7.58 dB. Even at the edge of the cell, the worst-case scenario shows a remarkable improvement in SINR from -29.06 dB to -7.34 dB, see Figure 126. These enhanced SINR values indicate that the link improved post Interference Mitigation and Co-existence Optimisation strategies have been successfully implemented. Now, the two systems are compatible and can guarantee seamless coexistence within the reference cluster, given the current conditions.

**Zone C Oltepesi Tinga: Mitigation Strategy 1 Co-Existence Average dRSS, Average Non-Interfered Bitrate and Non-Interfered SINR results**

After considering the Inter Site Distance of 15KM between the NPN sitesat Tinga and the Victim MNO site, the average dRSS remains relatively unchanged compared to the scenario where interference mitigation and coexistence optimisation are not taken into account. In fact, the average non-interfered bitrate and the non-interfered SINR in this scenario are not significantly different from the baseline coexistence study discussed earlier, prior to interference mitigation and coexistence optimisation. We show this Figures 121, 122, 123.

**Strategy 2: Multi-Channel Transmission between NPN and VLT MNO**

The second Interference Mitigation and Coexistence Optimisation strategy employed Multi-Channel Transmission between NPN and VLT MNO. This strategy retained the original inter-site distances for the Tinga NPN sites. However, the Tinga NPN site was transmitting at centre frequencies of 1825 MHz. Additionally, we expanded the MNOs receiver blocking response upper limit to +/-30 MHz at 50 dB and the NPN's ILT transmitters' out-of-band emission limits to +/-35 MHz at -65 dB to ensure experiment fidelity. The outcomes are as follows.

| Victim Results                | NPN ILT Link Results  |
|-------------------------------|-----------------------|
| Average bitrate loss : 0.049% | Sub-carrier ratio 0.2 |
| Sub-carrier ratio 1.0         |                       |

Table 30: Zone C Oltepesi Tinga: Mitigation Strategy 2 Co-Existence Results

After considering Multi-Channel Transmission between the NPN at Tinga and VLT MNO, the Average bitrate loss decreases to 0.049% as captured in Table 36. This represents minimal interference and falls within the permissible degradation to the LTE cell's performance specified by the OFDMA downlink/uplink system. Consequently, the two systems are compatible and can ensure seamless coexistence within the reference cluster.



## Zone C Oltepesi Tinga: Mitigation Strategy 2 Co-Existence Average dRSS, Average Non-Interfered Bitrate and Non-Interfered SINR results

After considering Multi-Channel Transmission between the NPN at Tinga and VLT MNO, the average dRSS remains relatively unchanged compared to the scenario where interference mitigation and Co-existence Optimisation are not taken into account. Similarly, the average Non-interfered bitrate and the non-interfered SINR in this scenario are not significantly different from the baseline coexistence study discussed earlier, prior to considering interference mitigation and Co-existence Optimisation. We show this in Figures 127, 128, and 129.

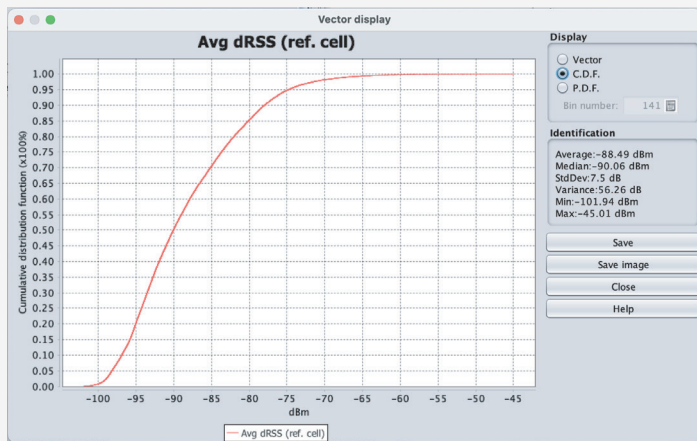


Figure 129: Zone C Oltepesi Tinga:  
Mitigation Strategy 2 Co-Existence Average dRSS

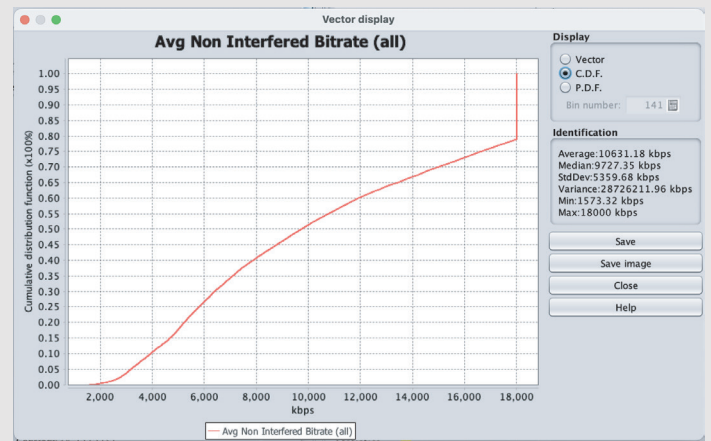


Figure 130: Zone C Oltepesi Tinga:  
Mitigation Strategy 2 Co-Existence Average Non-Interfered Bitrate

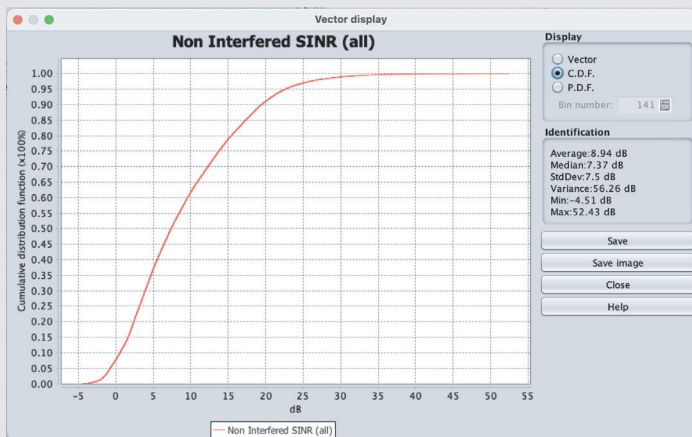


Figure 131: Zone C Oltepesi Tinga:  
Mitigation Strategy 2 Co-Existence Non-Interfered SINR results

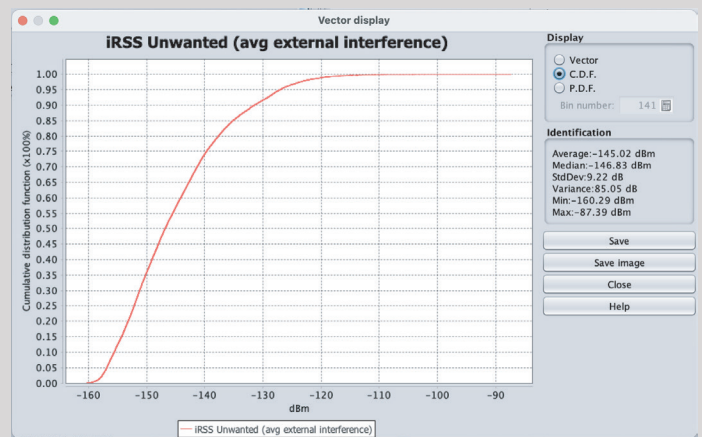


Figure 132: Zone C Oltepesi Tinga:  
Mitigation Strategy 2 Co-Existence Interference iRSS results

In contrast, when considering Multi-Channel Transmission between the NPN at Tinga and VLT MNO, the interfering Received Signal Strength further decreases, from -113.89 dBm when the intersite distance is 15 km to -145.02 dBm. This represents an even more significant improvement. The median Unwanted Interference (iRSS) also drops from -114.53 dBm to -146.83 dBm. This is shown in Figure 130. The worst-case scenario also decreases further from -128.44 dBm to -160.29 dBm. All these improvements indicate an enhanced link with minimal interference from the ILT when Multi-Channel Transmission between NPN and VLT MNO is considered.

When considering Multi-Channel Transmission between the NPN at Tinga and VLT MNO, the average bitrate demonstrates indications of an improved link as seen in Figure 131. This value increases from 10.3 Mbps when the Inter Site Distance between the NPN site and Victim MNO Site is 15KM to 10.6 Mbps. Furthermore, more than 23% of the scenarios can attain the maximum bitrate during transmission at 18Mbps. Conversely, less than 1% of the scenarios transmit at a minimum transmission rate of 1.5Mbps. In general, the coexistence strategy of Multi-Channel Transmission between the NPN site at Tinga and VLT MNO demonstrates an improvement in the average bitrate.

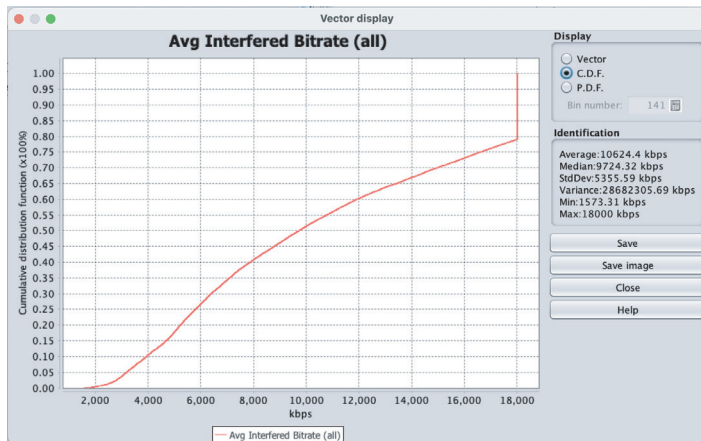


Figure 133: Zone C Oltepesi Tinga:  
Mitigation Strategy 2 Co-Existence Interference Average Bitrate results

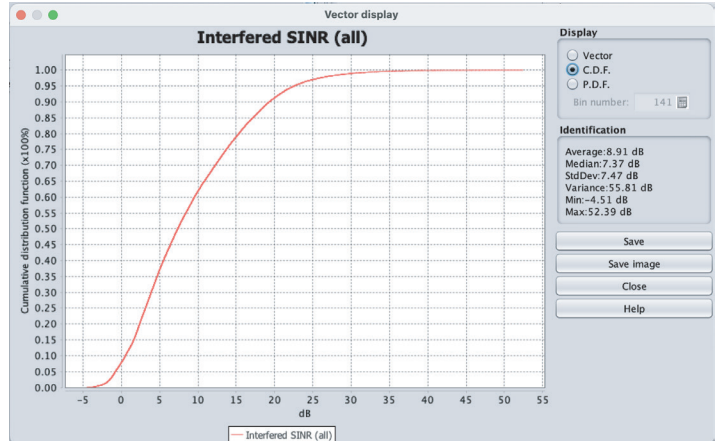


Figure 134: Zone C Oltepesi Tinga:  
Mitigation Strategy 2 Co-Existence Interference Interfered SINR results

The interfered SINR Multi-Channel Transmission between the NPN at Tinga and VLT MNO also improves. The previous average SINR of 2.1 dB has increased to 8.91 dB. The median SNIR has also increased from 2.03 dB to 7.37 dB. These improvements as seen in Figure 132 indicate that an enhanced link post interference mitigation and coexistence optimisation strategies have been successfully implemented. The two systems are now compatible and can guarantee seamless coexistence in the reference cluster.

# Coexistence Analysis Conclusion and Recommendations

This study has modelled the coexistence between NPNs and MNO-deployed sites in the 1800 MHz band. The results indicate that frequency reuse in areas where MNO sites are near potential NPN sites will be detrimental to the MNO as the incumbent. Based on the coexistence analysis in this report, two strategies have been explored to ensure dynamic spectrum access and coexistence between NPNs and MNO sites in the 1800 MHz band. Therefore, the recommendations for this study to ensure coexistence and mitigate interference between NPNs and MNOs in the 1800 MHz band are as follows:

1. Potential NPN sites must maintain a minimum exclusion zone of 15 km from the base station. This minimum exclusion zone also applies to any other adjacent NPN site.
2. The transmit power of NPNs should be capped at 1 W or 30 dBm.
3. The antenna height of NPNs should be capped at 20 meters in rural areas.
4. When deployed with an Omni antenna, NPN sites should aim for a 2.5 km coverage area to effectively meet both capacity and coverage demands.
5. The placement of NPN sites should be guided by the location of communities. This is because the small cell coverage area may prevent transmitting and covering areas with no subscribers. If necessary, we recommend tilting the antenna to focus the beams directly to communities and households to maximise coverage and capacity while simultaneously avoiding overshooting signals from non-tilted antennas that may interfere with MNO cells covering cell edges, particularly in hilly regions.

# Technical Analysis in the C-band (3.6-4.2 GHz)

## Overview

The 3600-4200 MHz (Band n77/n78) frequency spectrum range, has emerged as a strategic resource for enabling advanced wireless connectivity worldwide. In Kenya, this band presents a significant opportunity to support the development and deployment of Non-Public Networks (NPNs), specifically Private 5G networks (P5G). Its favourable propagation characteristics and ample bandwidth make it well-suited for these applications, offering the capacity required for high data rates, low latency, and robust coverage.

As Kenya continues its digital transformation journey, harnessing the potential of the Band n77/n78 can accelerate the adoption of Industry 4.0 technologies, foster innovation, and bridge the digital divide. Strategic allocation and management of this spectrum for NPNs will be essential in unlocking new economic and social value across the country.

Band n77/n78, categorised as the C-band (3400-4200 MHz), has become one of the highly contested bands that is traditionally home to a large number of satellite (space-to-Earth) transmissions and in many countries, fixed point-to-point or point-to-multipoint services. Fixed Satellite Services (FSS) receiving earth stations operate in the space-to-Earth direction in the 3400-4200 MHz. These earth stations can generally be grouped into four categories: earth stations deployed ubiquitously and/or without individual licensing or registration; individually licensed earth stations; telemetry earth stations; and earth stations that are feeder links for mobile-satellite systems.

This band is the band of choice for a multitude of services, including very small aperture terminal (VSAT) networks, internet providers, point-to-multipoint links, satellite news gathering, TV and data broadcasting to satellite master antenna television (SMATV), direct-to-home (DTH) receivers, and disaster relief. In many countries receive only earth stations or VSAT terminals are not individually licensed, and their number, location or detailed characteristics are not typically available. This band is also used by governments in conjunction with international commitments, for example, WMO uses this band to distribute meteorological data through commercial satellite systems.

Multiple studies have been conducted across a number of administrations and in collaboration with industry bodies for compatibility between FSS and public 5G systems. While yielding different results, key considerations from the compatibility studies include:

- Use of separation distances measured in tens to hundreds of kilometres (km) for operating 5G services co-channel in the band, unless the usage of the band is at a few, very remote or rural sites.
- Additional considerations are needed for operating 5G services in channels adjacent to wanted FSS signals. The out-of-band (OOB) emissions from 5G transmitters and the potential for overloading the receiver mean that this scenario requires very careful modelling to correctly understand the impacts.
- Emission masks for the IMT system should make use of the recent standards as opposed to earlier standards as that presents limited use in the present status of 5G FSS sharing. Concerns of mobile equipment manufacturers exceeding requirements beyond those in the 3GPP standards to be considered.



- Where filtering is applied to Low-Noise Block (LNB) downconverter, it needs to be sufficiently wideband to allow adequate operation within the available FSS spectrum.
- All of the thresholds which are defined with respect to satellite receiver performance (e.g. the non-linearity compression point of the LNB, or an increase in I/N) represent limits at and as such, should not be assumed to be targets to be met. The calculation results should also be treated the same – showing points at which reception is degraded and not an average value of determining network roll-out parameters.
- Practical considerations of reflections from nearby structures is necessary for higher FSS elevation angles as other studies have shown that the theoretical rejection provided by increased elevation angles does so little to mitigate against 5G interference.
- Given the limitation to control the separation distance between user devices and satellite dishes, a trade-off between the size of any guard-band left between 5G and FSS, the necessary separation distance between transmitters and receivers and the performance of any filters fitted to the satellite receivers.

## Summary Status of C-band in Africa – and Kenya

The C and Ku bands have historically been used for commercial geostationary communications services. However, the C-band has continued to be used over the other bands due to the availability of deployed equipment, minimal impact of rain attenuation i.e. good link availability and wide beam coverage areas with up to 30% of the earth's surface able to be covered by a single satellite.

As at 2021, there were no C-band Direct-to-Home (DTH) television services in Africa. However, there was a total of 54 satellites with C-band coverage of at least a portion of Africa providing 43.3 GHz of capacity. Of the 54, 42 have coverage of Johannesburg with at least one beam. Many satellites have beams with coverage of regions outside of Africa, specifically on hemi, landmass and global beams. Mobile backhaul and trunking applications represent (as at 2021) 77% of the total African C band usage with Television distribution and contribution using 19%. These two applications thus make up more than 96% of the C band usage on the continent. Angola has been building a High-Throughput Satellite (HTS) telecommunication network since 2021 named ANGOSAT2 that targets to provide services in the unplanned services in C and Ku-bands.

In Kenya, the 3400-3600 MHz has been identified for IMT, However, the band is primarily licensed to FSS (space-to-Earth). Recent satellite initiatives have shown collaboration between Kenya Broadcasting Corporation's (KBC's) Signet Digital Terrestrial Television (DTT) being broadcast via the advanced AMIS-17 HTS. KBC's Signet broadcasts over 70 TV stations and a host of radio channels throughout Kenya and into South Africa. AMOS-17 utilises C-band enabling KBC realise significant network performance improvements.

Spectrum measurements conducted during the site visits in Kajiado County, however, showed very minimal activity in the band. Tuned to a centre frequency of 3900 MHz across all the visited sites and using CA's spectrum analyser, there was no signal received in the band above the noise floor of (-115.7 dBm) as shown from Figure 135 to 143.

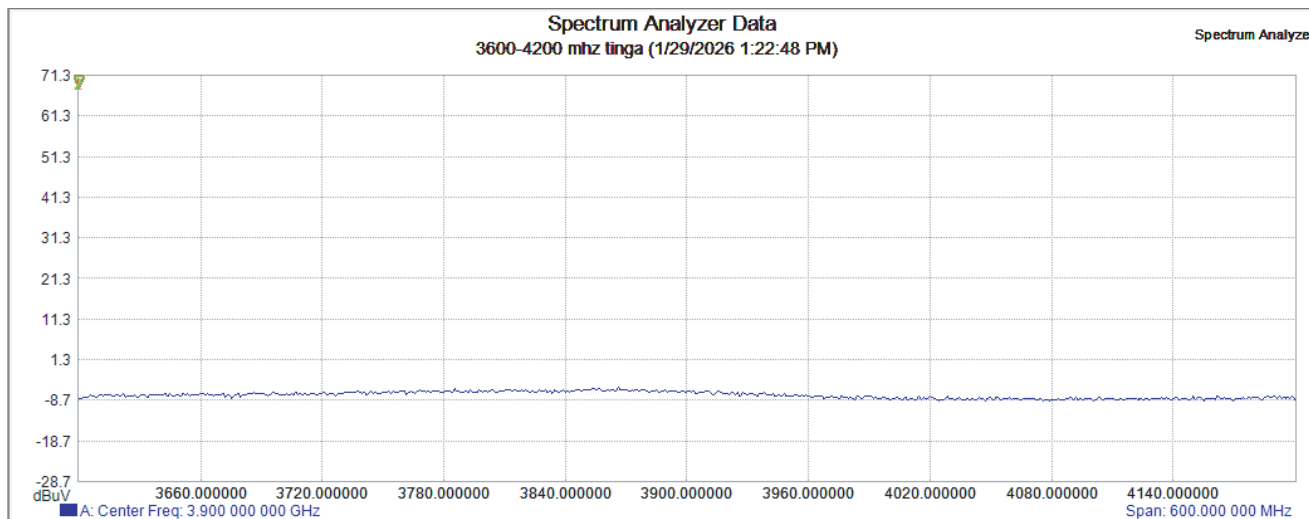


Figure 135: Spectrum Measurements in the C-band at the Tinga Site

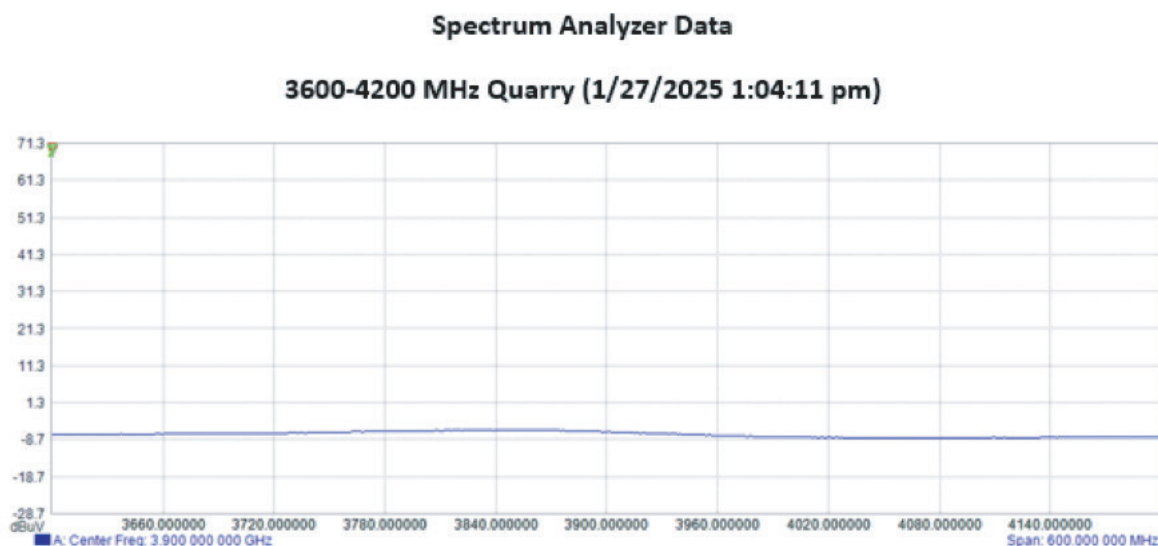


Figure 136: Spectrum Measurements in the C-band at the Olepolos Quarry Site

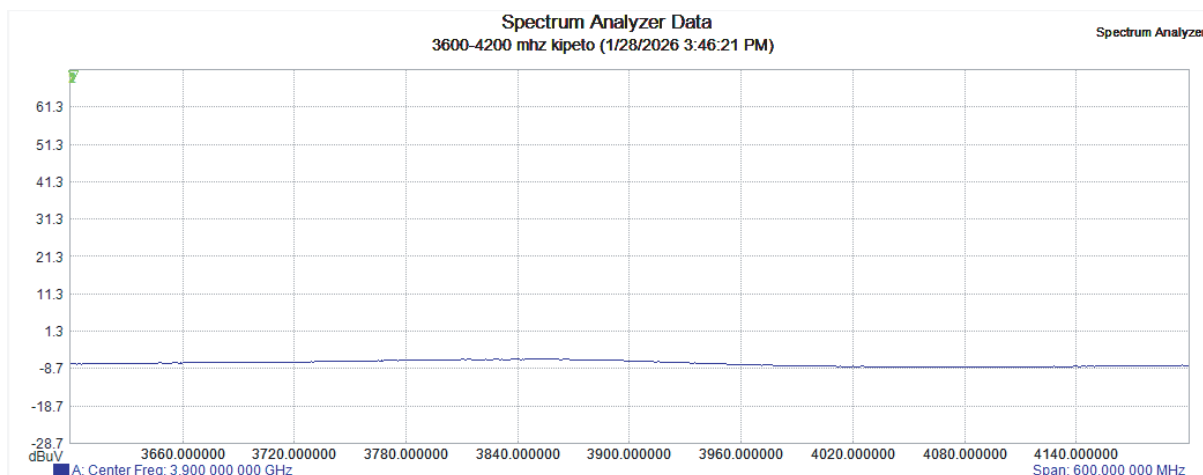


Figure 137: Spectrum Measurements in the C-band at Kipeto Site

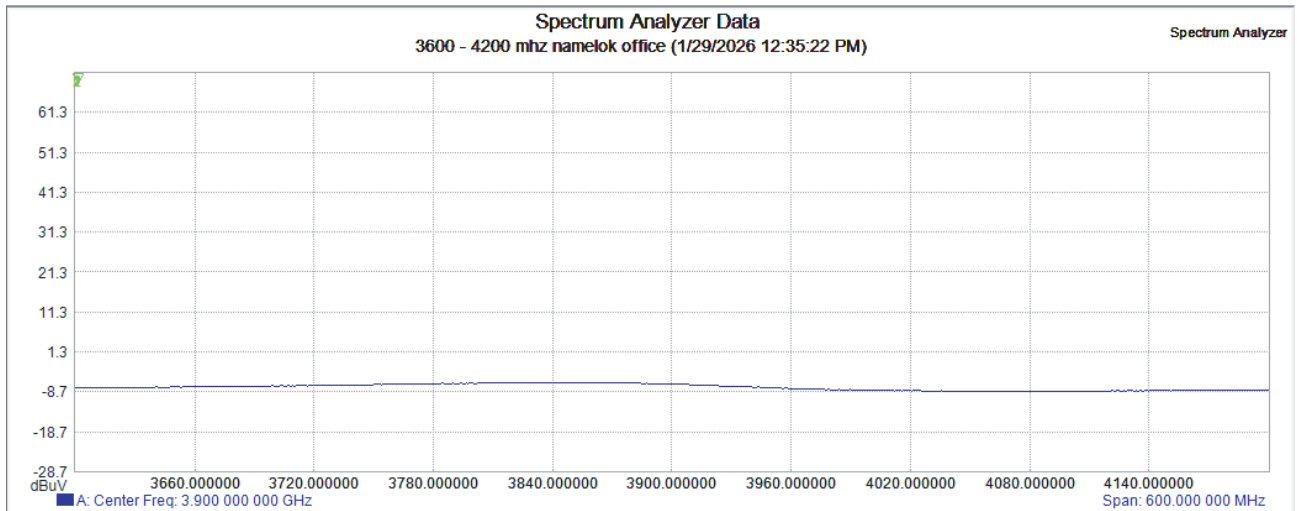


Figure 138: Spectrum Measurements in the C-band at the Namelok Office

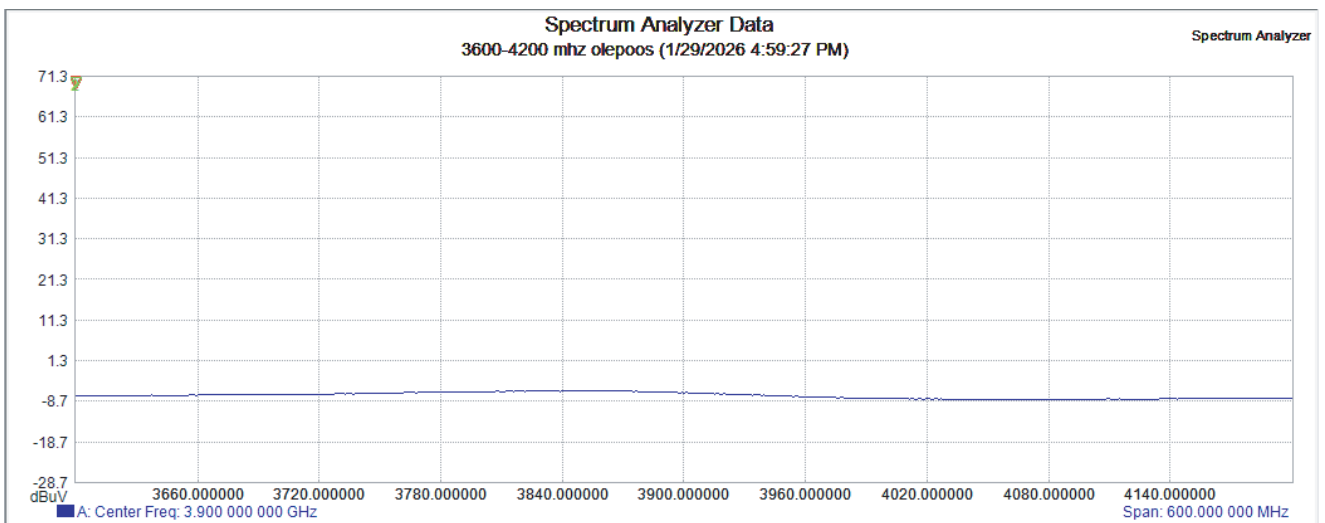


Figure 139: Spectrum Measurements in the C-band at Olepolos Tower Site

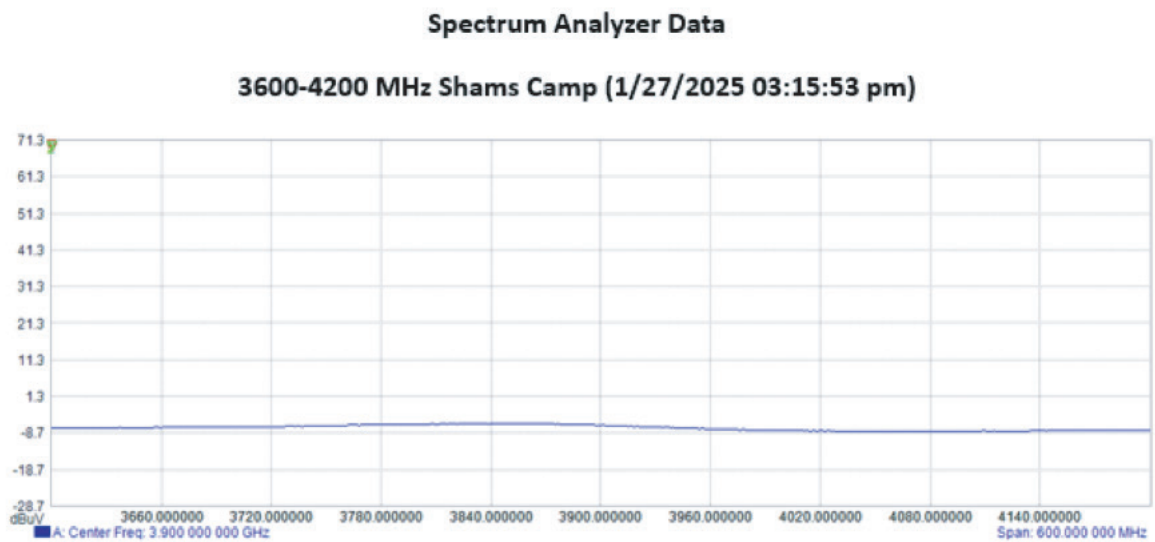


Figure 140: Spectrum Measurements in the C-band at Sham's Camp

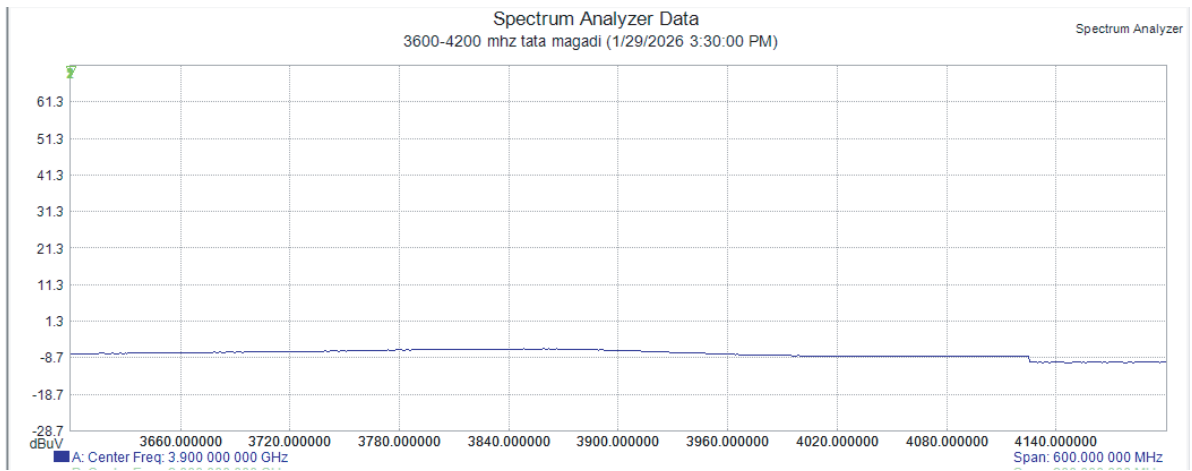


Figure 141: Spectrum Measurements in the C-band at the Magadi Site

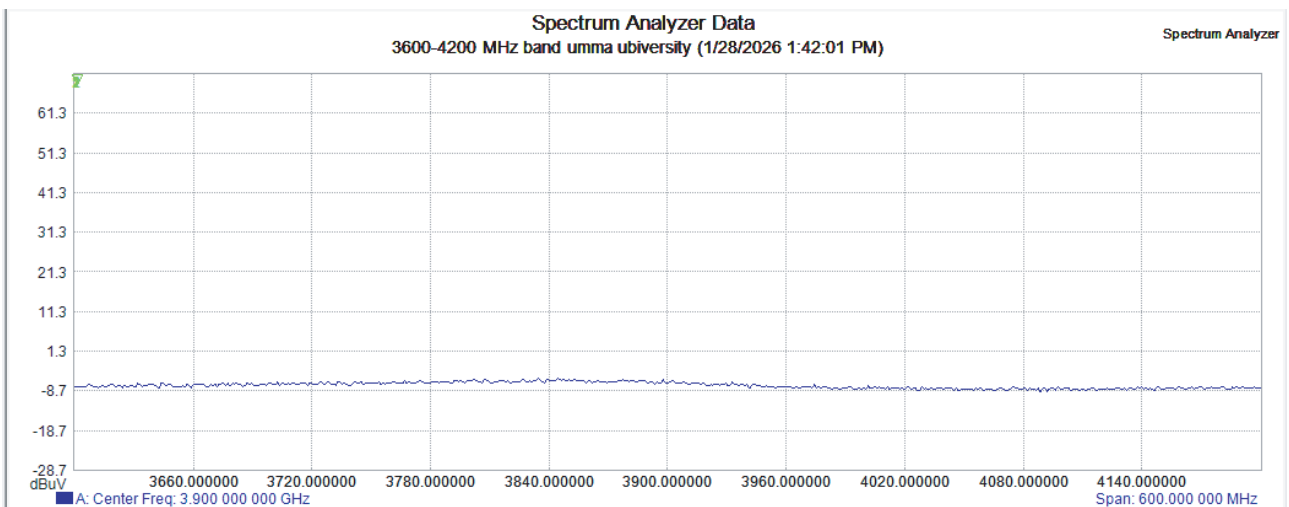


Figure 142: Spectrum Measurements in the C-band at the Umma University (on the ground)

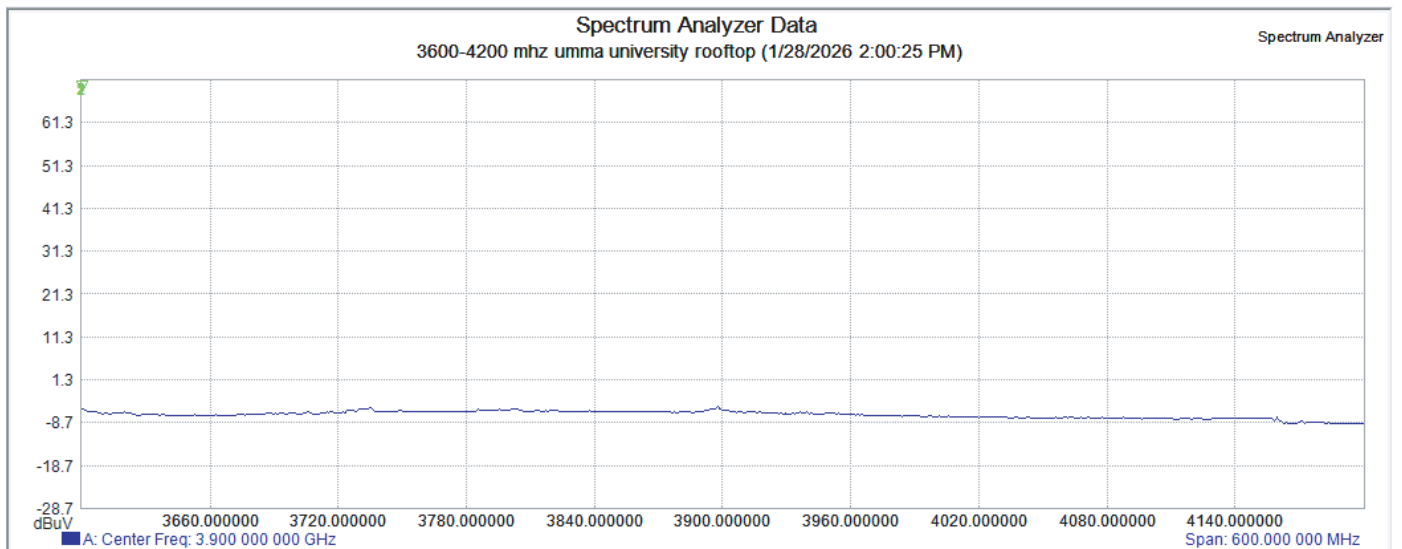


Figure 143: Spectrum Measurements in the C-band at Umma University (measured from the rooftop)



## Public IMT Access in the C band

The C band (3400-3600 MHz) had already been identified for IMT by CEPT in 2007 and a more global scale was achieved at WRC 2015. The 3600-3800 MHz – despite being promoted by CEPT – was not marked for IMT at WRC-15 [2]. At the WRC-23, the allocation of the frequency band 3400-3600 MHz to IMT stipulated a provision that the power flux-density (pfd) for mobile services (base or mobile stations) produced by one administration at 3m above ground should not exceed  $-154.5 \text{ dB} \left( \frac{W}{m^2} \cdot 4 \text{ kHz} \right)$  for more than 20% of time at the border of the territory of any other administration. Stations of the mobile service in the frequency band 3 400-3 600 MHz are also not to claim more protection from space stations under the provisions in Table 31.

Table 31: Limits of Power Flux-density from Space Stations

| Frequency Band | Service                                                                                                                                  | Reference Bandwidth | Limit in dB $\left( \frac{W}{m^2} \right)$ for all angles of arrival above the horizontal plane |                                         |         |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------|---------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------|---------|
|                |                                                                                                                                          |                     | 0°-5°                                                                                           | 5°-25°                                  | 25°-90° |
| 3400-4200 MHz  | Fixed-satellite (space-to-Earth) (geostationary-satellite orbit)<br>Fixed-satellite (space-to-Earth) (non-geostationary-satellite orbit) | 4 kHz               | -152                                                                                            | "-152 + 0.5(δ - 5)"                     | -142    |
| 3400-4200 MHz  | Fixed-satellite (space-to-Earth) (non-geostationary-satellite orbit)                                                                     | 1 MHz               | "-138 - Y 22, 23"                                                                               | -138 - Y + (12 + Y)(δ - 5) / 20 22, 23" | -126 23 |

A possible system model of deploying mobile networks as secondary licensed users in the 3600-3800 MHz is shown in Figure 144 where the mobile network operator accesses the band using low-power communication i.e. small cells and device-to-device (D2D) mode. This model is based on an LSA approach. Unlike macro base stations that require tens of kilometres of protection distances around satellite earth stations, the low-power transmissions can operate even closer than 1km from the FSS very small aperture terminal (VSAT) receivers.

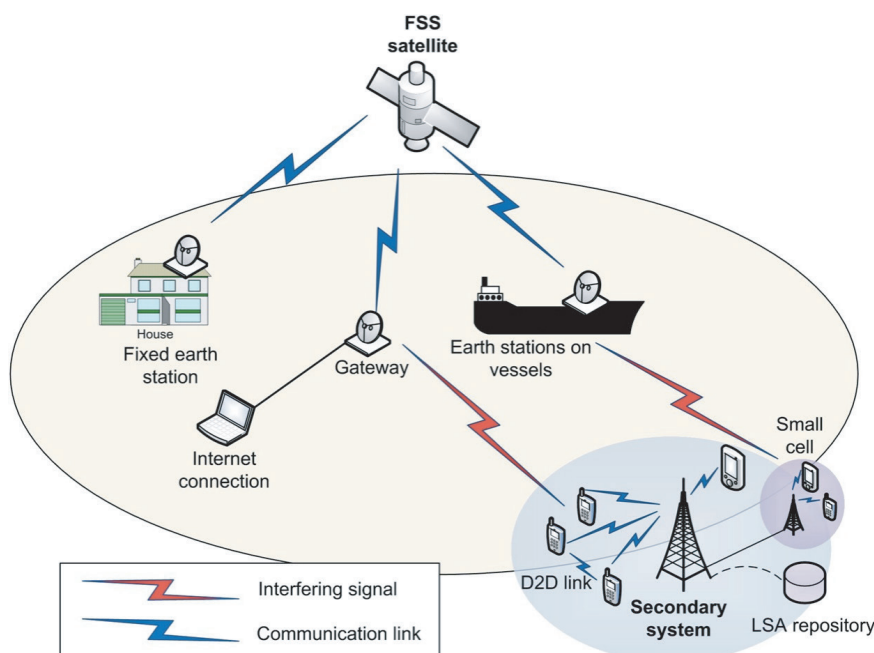


Figure 144: C-band sharing with an LSA approach

(Source: TV White Space Communications and Networks by Stewart, Crawford, & Stirling Andrew, 2018)

## Coexistence and Compatibility Analysis in the C-Band

In the context of NPNs, the coexistence analysis in the C-band (considerable in the range of 3400-4200 MHz) evaluates potential co-channel and adjacent-channel interference to ensure that the NPNs (Private 5G) do not disrupt -or suffer degradation from – incumbent services (FSS) or public mobile networks. Hence, the key interference scenarios are:

1. Private 5G to FSS (space-to-Earth): Private 5G (P5G) base stations (gNBs), operating near C-band satellite dishes can cause LNB (Low-Noise Block) saturation and in-band interference if adequate separation or filtering is not maintained.
2. Private 5G to Public IMT: If the Private 5G (P5G) network uses shared or adjacent spectrum (similar to CBRS), macro networks deployed by a public IMT network can impact median downlink throughput of the private network.

The technical conditions for compatibility between a 5G device (base station or UE) and a C-band satellite terminal are a function of numerous factors which make it impossible to provide a generalised analysis, and each scenario needs to be evaluated on a case-by-case basis – as studies conducted yield different results. In this case, we provide the analysis for Kenya, particularly for Kajiado County (and more specifically for the identified potential P5G sites), while borrowing from the work done by Numerous FCC, CEPT, ITU and other industry groups such as LS Telecom.

Although the 3400-3600 MHz has been identified for IMT in Kenya, measurements conducted in Kajiado County show that IMT deployments are yet to take place in the C-band. Hence, the compatibility assessment presented in this document only consider the Interference Scenario 1 – Private 5G to FSS. Scenario 2 above is therefore not evaluated in this case. Notably, given the present state of non-existence of public IMT deployments in the already assigned bands in Kajiado, the analysis holistically adopts their (Public IMT parameters) to guide the NPN potential deployments as secondary users of the band. However, a recommendation is provided for future consideration depending on the evolution of deployments by MNOs.

Introducing IMT services into the C-band band is far more complex than for previous fixed services if satellite reception is to be protected as:

- Mobile base station transmissions are much higher powered;
- Mobile base stations transmit in all directions and not just on a point-to-point basis;
- User devices can be anywhere, making controlling their proximity to satellite receivers nigh on impossible.

A wide range of organisations have tried to determine how mobile services could share spectrum with satellite services (and fixed services) and with a push towards using the band for 5G services, the importance of finding workable solutions has never been greater. According to documented benchmarks from several countries, the recommended exclusion distances vary according to deployment scenarios and environmental conditions. For example, the United States proposes a minimum separation of 20 km between 5G transmitters and FSS Earth stations. In Hong Kong, China, simulation-based analysis for macro cell environments recommends a radius of 25 km. Meanwhile, in the Netherlands, a broader exclusion range of 20 to 50 km has been established, depending on frequency usage and urban or rural deployment contexts.

Based on the data shared by CA in Table 32, our analysis focuses on the receiving FSS earth station at RMS Brackenhurst in Limuru, Kiambu County which is at least 77.2 km away from the first potential site for P5G in Kajiado county at Orly Park (considered as a single base station). Other potential sites are Umma University (101 km from the incumbent site) and Magadi Soda (139 km from the incumbent sites). The Brackenhurst site, shown in Figure 145 (“yellow dot”) is the only space-to-earth (downlink receiver) station. The “blue dots” are earth-to-space stations in the 6 GHz band. The “purple dots” represent the identified potential sites for NPNs in Kajiado county. Figure 146 represents the same with the naming of the FSS sites as provided in the CA data.

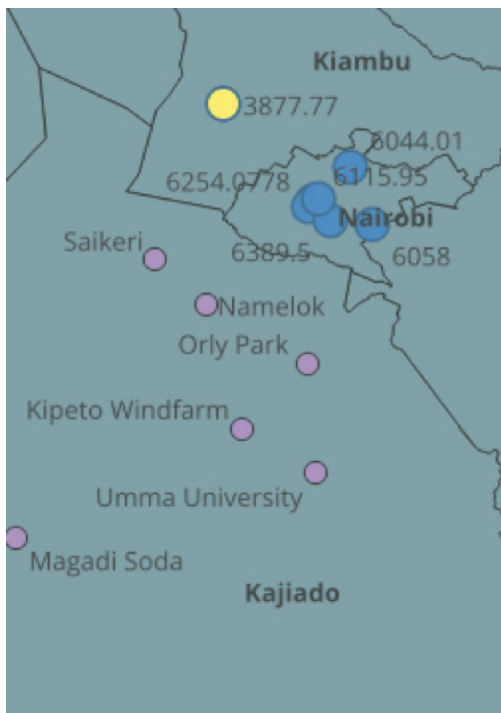


Figure 145: FSS stations alongside Namelok's target sites for NPNs Deployments

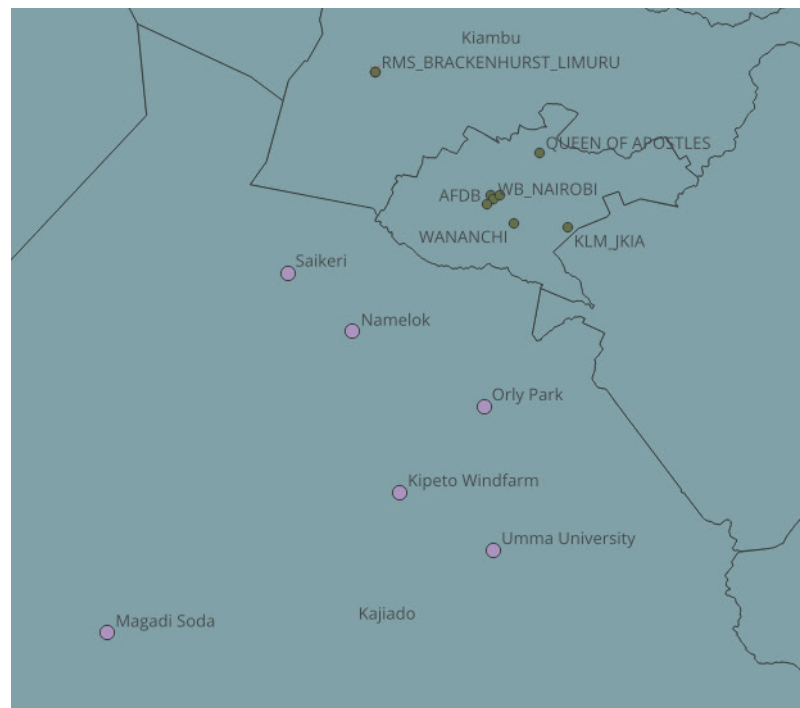


Figure 146: Sites with the names of FSS stations

In the analysis of compatibility between the NPNs and the incumbent FSS systems operating in the C-band (3400-4200 MHz range), two interference scenarios are considered and recommended: NPN (IMT) base station into FSS earth station and IMT user equipment (UE) into FSS earth station. However, given the initial targeted deployments for P5G networks as Fixed Wireless Access (FWA) networks, the second scenario is left for future analysis. Hence, the consideration in this case only focuses on the single NPN base station interference to the FSS earth station.

## Protection Criteria

To determine whether or not the RMS Brackenhurst station requires protection (and if so, how much protection) against interference that may originate from the NPN network (considered as an IMT network), the criteria given in Recommendation ITU-R SF.1006 and ITU-R Report S.2368 are used. These documents describe the long-term, short-term and blocking criterion to be met.

The Long-term interference criterion is based on ITU-R S.1432 and considers both in-band and adjacent-band cases and requires that the total interference not to exceed 10% of the system noise level for more than 20% of the time. This criterion is used to ensure that the minimum desired quality of the received satellite signals is met for most of the time. This translates to co-primary systems to have an  $I/N = -12.2$  dB (for 100% of the worst month,  $\Delta T/T$  can only increase by 6% due to this interference) and  $I/N = -10$  dB (for 20% of any month,  $\Delta T/T$  can only increase by 10% during this time). The adjacent band interference should be kept at  $I/N = -20$  dB (for 100% of the time,  $\Delta T/T$  to be kept less than 1%).  $N$  is the clear-sky satellite system noise as described in Recommendation ITU-R S.1432.

The Short-term interference criterion is based on ITU-R SF.1006 and requires the level of interference not to exceed the maximum permissible interference level for more than 0.005% of the time. with fade margin  $MS = 2$  dB; link noise contribution by the satellite transponder including uplink noise  $NL = 1$  dB and thermal noise equivalence factor for interfering emissions  $W = 0$  dB).

The blocking criterion requires the total received interference power not to exceed -61 dB. This criterion is used to prevent the receiver's Low Noise Amplifier (LNA) or Low Noise Blocks (LNBs) from being driven outside its dynamic range where it exhibits non-linear behaviour (resulting in intermodulation products and gain compression). Since the LNA is a wideband device, intended to have a low noise figure and flat frequency response over the frequency band of 3400-4200 MHz, this blocking criterion is applicable in the total downlink frequency band of 3400-4200 MHz. This criterion is adopted in scenarios of LNA/LNB overdrive.



## The Analysis

Given Kenya's context of the current incumbent RMS Brackenhurst FSS station (a Cable TV headend), the distance of at least 77.2 km between the FSS station and the potential NPN sub-urban scenario at Orly Park in Kajiado presents an allowable separation distance (also as the path length) equivalent to the scenarios and recommendations presented in the ITU-R Report S.2368. The distance shows that both long-term and short-term protection criteria can be met for the in-band emissions while considering the deployment as a single interferer operating as a Fixed Wireless Access (FWA) station.

| Parameters            |           | Value used in the Analysis                         |
|-----------------------|-----------|----------------------------------------------------|
| Station/Type          |           | INTELSAT/IS-902                                    |
| Coordinates           | Latitude  | 1° 06' 56" S                                       |
|                       | Longitude | 36° 39' 39.29" E                                   |
| Altitude (m)          |           | 2247                                               |
| Elevation Angle (Deg) |           | 227                                                |
| Antenna Gain          |           | ITU-R S465-6 (with elevation provided by CA above) |
| Azimuth Angle (Deg)   |           | 57                                                 |
| EIRP (dBW)            |           |                                                    |
| Tx Freq (MHz)         |           | "6096.3275 MHz 6102.77 MHz"                        |
| Tx Bandwidth (MHz)    |           | 4.6 MHz                                            |
| Tx Capacity (MHz)     |           | 10000                                              |
| Rx Freq (MHz)         |           | "3871.3275 MHz 3877.77 MHz"                        |
| Antenna Gain (dBi)    |           | 60.8                                               |
| Antenna Diameter      |           | 7.2                                                |
| Nominal Power (W/dBm) |           | 66                                                 |
| EIRP (W)              |           | 47                                                 |
| Clutter Category      |           |                                                    |

Table 32: FSS Earth STATION Parameters

Table 33: Potential NPN (IMT) Base station Parameters

| Base Station Characteristics/Cell Structure        | Value used in the Analysis                                                                                                                                                                                                                                                                                                        |
|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cell radius/Deployment Density                     | 0.3 - 2km (typical figure to be used for sharing studies<br>0.6km)                                                                                                                                                                                                                                                                |
| Frequency range                                    | 3400-4200 MHz                                                                                                                                                                                                                                                                                                                     |
| Peak gain (Maximum base station antenna gain)      | 18 dBi                                                                                                                                                                                                                                                                                                                            |
| Antenna Height (m)                                 | 25m                                                                                                                                                                                                                                                                                                                               |
| Sectorisation                                      | 3-sectors                                                                                                                                                                                                                                                                                                                         |
| Downtilt                                           | 6 degrees                                                                                                                                                                                                                                                                                                                         |
| Frequency Reuse                                    | 1                                                                                                                                                                                                                                                                                                                                 |
| Antenna pattern                                    | "Recommendation ITU-R F.1336<br>– ka = 0.7<br>– kp = 0.7<br>– kh = 0.7<br>– kv = 0.3<br>Horizontal 3 dB beamwidth: 65 degrees<br>Vertical 3 dB beamwidth: determined from the horizontal<br>beamwidth by equations in Recommendation ITU-R<br>F.1336. Vertical beamwidths of actual antennas may also<br>be used when available " |
| Antenna Polarisation                               | linear / ±45 degrees                                                                                                                                                                                                                                                                                                              |
| Feeder loss                                        | 3 dB                                                                                                                                                                                                                                                                                                                              |
| Maximum base station output power/sector (e.i.r.p) | 61 dBm/20 MHz                                                                                                                                                                                                                                                                                                                     |
| Clutter Category                                   | Village centre                                                                                                                                                                                                                                                                                                                    |
| Signal Bandwidth                                   | 10 MHz                                                                                                                                                                                                                                                                                                                            |

Propagation loss is based on Recommendation ITU-R P.452-16 (with adoption of inputs from the latest revision 18). This recommendation has been used in the various studies in the 3 400-4 200 MHz band. The analysis in this study considers the clutter category of the RMS Brackenhurst FSS station as Village centre while the clutter category of the potential NPN site as Suburban and achieves the aggregate propagation loss as shown in Figure. The propagation characteristics used in this analysis are shown in Table 34. Figure 147 shows the propagation loss obtained from the values used within a MATLAB function developed by Ofcom for P.452-16.

Table 34: Propagation characteristics

| Parameter                                     | Macro Suburban |
|-----------------------------------------------|----------------|
| Model                                         | P-452-18       |
| Percentage of time basic loss is not exceeded | 20%            |
| Average radio-refractive index lapse rate     | 45 N-units/km  |
| Sea-level surface refractivity                | 330 N-units    |
| Path centre latitude                          | 40 N           |
| Clutter height                                | 9m             |
| Clutter distance                              | 0.025          |

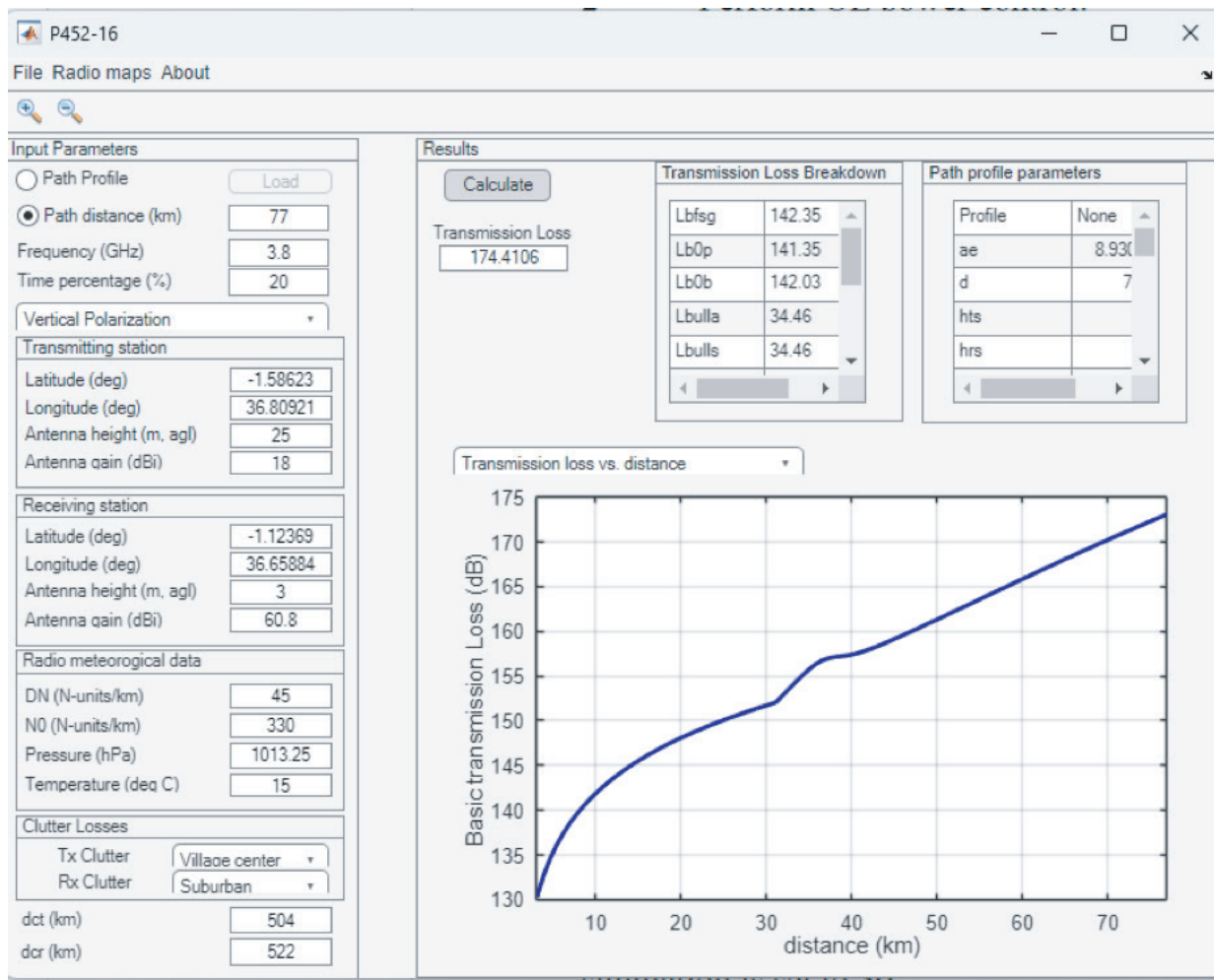


Figure 148: Propagation LOSS ON ITU-R P.452-16

Calling the Ofcom propagation loss API in the analysis using the datasets from Table 32, 33 and 34, we obtain a minimum separation distance at 70km as shown in Figure 148 with the consideration of long-term protection criterion of  $I/N = -12.2$  dB.

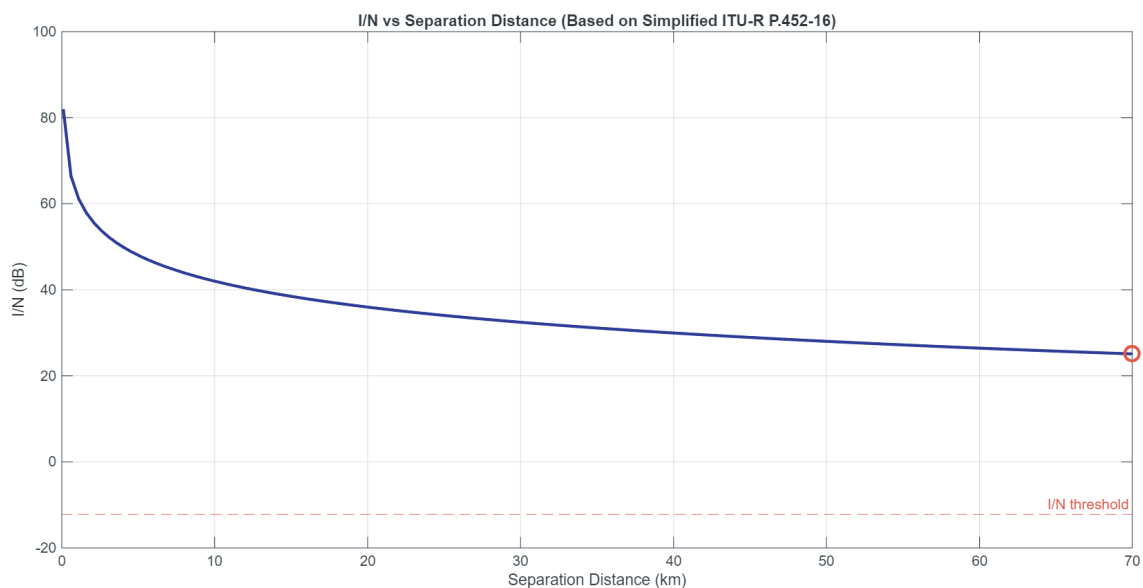


Figure 149: Plot of Minimum separation distance

## Conclusions

The analysis demonstrated in this context only considers a single NPN interferer operating as co-primary in the C-band (selected centre frequency to be 3800 MHz) as the incumbent RMS Brackenhurst FSS station. The analysis only focuses on a long-term interference scenario. Although consideration for this analysis strongly borrows the IMT-Advanced recommendations from the ITU-R S.1432 report (in the 3400-4200 MHz) which stipulate national deployments, it should be noted that the scenario for an NPN would be different. Some regimes note that local deployments of 5G (a case like the Orly Park) are not taken into account for many of the coexistence calculations. Taking the example of Netherlands, local deployments of 5G are said to still have many unknowns (i.e. number of the deployments, their locations, coexistence requirements for local deployments that may also need to consider radars below 3400 and satcom system above 3800 MHz) for inclusion into coexistence analysis.

The mitigation effort for coexistence in this band is also based on achieving a given exclusion distance (protection or separation distance). The separation distance defines a distance from the FSS station within which no deployment of 5G is allowed (in our case, P5G NPN). Additional mitigation measures can be included by further analysis of the LNAs and provision of recommendations for the filters. However, this study (again) has only evaluated one FSS interference mechanism of an in-band “NPN” emission. It has also not evaluated the unwanted emissions from UE to the FSS station.

The protection distance derived from the analysis just builds onto the site measurements conducted in Kajiado by CA. While the path distances of 77km (Orly Park), 101km (Umma University) and 139km (Magadi Soda) fit within the protection distance of 70km for macro sub-urban deployment (equivalent to the range of protection distances in ITU-R S.1432), the measurements carried out by CA should be taken into account because of the assignment of 3400-3600 MHz to MNOs.



## Recommendations

**Case-by-Case Approach:** Drawing from the Netherlands' experience, Private 5G deployments should be evaluated individually. The variability in local conditions means that exclusion (protection) distances will differ from site to site, depending on unknowns such as deployment density, terrain, and proximity to the FSS station. Adjacent band interference, consideration for short-term interference criterion alongside the anticipated public IMT deployments in the 3400-3600 MHz should also be considered as part of case-by-case interference analysis in future.

**Interference Risk:** For locations distant from the RMS Brackenhurst FSS station, interference from P5G is unlikely to be a concern. However, potential issues may arise when Private 5G networks use shared or adjacent spectrum alongside Public IMT (e.g., CBRS-like arrangements). In such cases, macro networks operated by public IMT providers could negatively affect the median downlink throughput of private networks.

**Future Technical Analysis:** A technical study is recommended for scenarios where Public IMT and Private 5G networks are deployed together, to fully understand mutual interference and performance impacts.

**Data Consolidation and Mitigation:** As recommended in the 2024/2025 NPN Analysis study, the Communications Authority (CA) should consolidate all relevant datasets, including detailed specifications of the RMS Brackenhurst FSS station. This will help determine if further mitigation measures are required, including the possible need for LNA/LNB overdrive mechanisms or enhanced filtering.

## References

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